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RESEARCH—THE YEAST IN THE LOAF OF AGRICULTURE

By H. A. WALLACE

SECRETARY OF AGRICULTURE

BACK of practically every activity of the Department of Agriculture there is a research problem, scientific or economic. This is putting it mildly, sometimes there are a dozen problems, all pressing for solution at once Yet though research is basic to almost all the many government functions relating to agriculture, it gets only a meager part of the funds used in carrying out these functions, and only a small part of the personnel In 1932 the appropriation for research, exclusive of payments to states, was 6 per cent of the total budget for the Department In 1935, when the budget was, of course, swelled by emergency activities, the appropriation for research was less than 1 per cent. of the total. Of the Department personnel of 45,000, some 7,000 are technical workers, and not by any means all these are engaged in research even part of the time.

The Department's work may be likened to a loaf of bread, of which the smallest part, research, is the yeast that leavens the whole loaf; or to a pyramid standing not on a broad base but on a narrow apex of research. If there is not enough yeast, or if it is of poor quality, the loaf will be only half risen; if the apex of the inverted pyramid is too small, the pyramid will topple over. There is no activity on which we can so ill afford to skimp

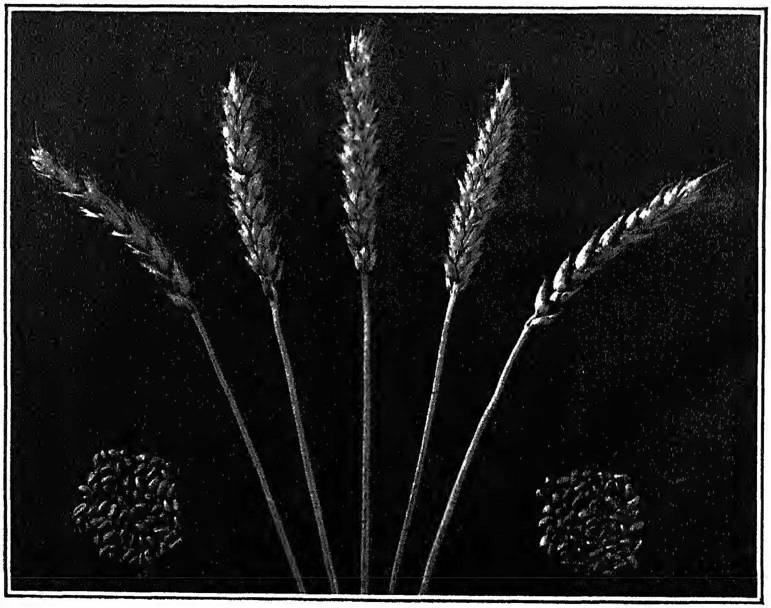
Just the same, even if it is done as economically as possible, with no fancy trimmings or elaborate gadgets, research comes high when there are a great many projects to be covered simultaneously. This is one of the reasons why it must be a government function in broad fields affecting millions of people, such as agriculture

Is it worth the cost? In 1935, an epidemic of stem rust damaged the wheat crop in North Dakota alone to the extent of $100,000,000 One of the research projects of the U. S. Department of Agriculture is the development of rust-resistant wheats, and in cooperation with the Minnesota Agricultural Experiment Station, a new spring wheat, Thatcher, was recently introduced which is more resistant to black stem rust than any variety ever distributed to farmers Where Thatcher was on trial in the 1935 epidemic, it came through with flying colors Here is a case where a single product of research might in a single state save many times the cost of the whole research program, covering all states and hundreds of projects Over 100 strains of black stem rust are now known, and it is likely that more will be found. Thatcher is resistant to almost all the known strains, but it may prove to be susceptible to other strains in the future. In that case, it will be the job of the scientist to develop another wheat

that will meet the new situation. This kind of work is continuous; there can be no let-up if man is to wage a successful battle against his natural enemies.

Just such savings have been made not once but many times. Hog cholera control is an outstanding example of the large returns research may make on the money invested. Moreover, the results of a given project may reach out far beyond what was originally intended or thought of. When workers in the Department of Agriculture found by patient investigation that the cattle tick was the carrier of tick fever, they had no notion that this discovery—which incidentally saved the cattle industry from a situation that was getting near panic—would blaze a trail along which other researchers might track down such deadly human diseases as yellow fever, malaria, African sleeping sickness, Rocky Mountain spotted fever and nagana, all of which proved to be carried by insect hosts. Such connections as this between one field and another are not uncommon. Research in animal nutrition, for example, is closely associated with research in human nutrition, and has led to important discoveries in that field. One of the fascinating and exciting things about science is that there is no telling where some obscure experiment may lead, or what new vistas it may open up.

I confess, then, that I don't have much patience with those who object to the amount of money spent on research. Some of the expenditure, without doubt, will be money thrown down the well. It never will give any return. And there is no sure way of knowing in advance just what will be worth while and what won't. Some of the most promising and elaborate projects turn out to lead up blind alleys; and contrariwise, some apparently insignificant hunch may bring extraordinarily fruitful results. Until all the basic facts and principles are



THATCHER—THE WHEAT OF THE HOUR!

IN LAST YEAR'S UNPRECEDENTED BLACK STEM RUST EPIDEMIC THIS SPRING WHEAT PRODUCED BY SCIENTIFIC RESEARCH WORKERS PROVED TO BE THE MOST RESISTANT TO THIS DISEASE OF ANY VARIETY YET DISTRIBUTED TO FARMERS.

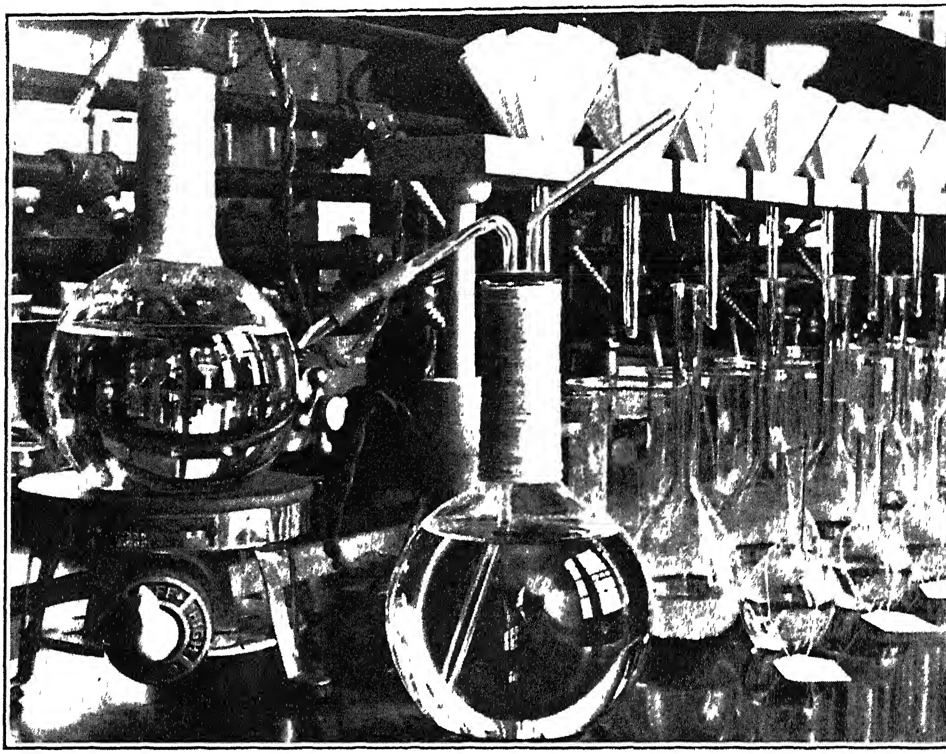
known, research must frequently take a shot in the dark But whatever may be the outcome in any given project, there can be no doubt that research as a whole pays its way many times over

This is not to say that it is not possible to waste both money and time in research Good judgment has to be exercised here as well as elsewhere, even though it is not always easy to know what is ahead of the times because it seems insane, and what is insane because it merely seems to be ahead of the times Again, equipment may be elaborated to the point where a man is so lost in admiring it that he forgets to think. A research man has to have adequate funds, and the proper tools, and a good reference library, but it is the man himself who counts most The history of science is full of the stories of men who did brilliant things with nothing to start with but a good brain, plus enough ingenuity and determination to make what they needed out of some odds and ends. Again, it is possible to waste time and money because the research man is so surrounded by administrators, directors and committees, and so wound up in a ball of red tape, routine and regulations, that he can hardly get free long enough to do any work All these elements are unfortunately necessary in a vast organization such as a federal department, but there must be a constant effort to simplify and cut through the clutter. The research worker in a large organization should be given a definite assignment and made responsible for it, but thereafter he should be bothered as little as possible. I feel that our research men must be relieved of some of the excessive amount of routine correspondence, answering of inquiries, *et cetera*, that now bedevils them

A Research Roll of Honor

Fortunately, the Department has always been able to attract men of high caliber. I would like to deviate from the subject and talk about that, but this is not the place for it. It is something to think about, however, that so many men and women who are the salt of the earth, if one may judge by hard work and worth-while achievement for mankind, have deliberately chosen, over many decades, to work in obscure government jobs for rewards that in many cases do not compare with what they might have had in private industry. There are motives at least as potent and lasting as the desire for gain, without which, some people argue, progress would stop and men would never do anything

Since the establishment of the Department of Agriculture in 1862, nearly 75 years ago, there have probably been at least a hundred Department scientists who have gained national and sometimes international fame for their work In the Bureau of Entomology and Plant Quarantine alone I can think of at least seventeen men of outstanding achievement, including B W Coquillett, who developed cyanide fumigation for insect pests; H. G Hubbard, who developed oil emulsion sprays; Albert Koebele, whose work on the natural parasites of insects has world-wide significance; W. E Dove, the medical entomologist who discovered that typhus may be transmitted by a certain mite; and F G. White, investigator of bee diseases. In other fields there are many more who might be added to a roll of honor for their service to mankind and particularly to agriculture —for example, N. A. Cobb, famous for his exact scientific research on nematodes; M Dorset, who worked out hog cholera serum; W. W. Garner, discoverer of the effect of length of day on the development of plants, Maurice Hall, who developed the carbon tetrachloride and more recently the tetrachlorethylene treatment for hookworm; C F. Marbut, whose work in soil classification has been outstanding; Cornelius L Shear, the mycologist who has done so much to enlarge our knowledge of the sac-fungi which



SCIENTIFIC WORK IN AGRICULTURE

HAS BECOME SO REFINED THAT BEST AND LATEST OF LABORATORY EQUIPMENT IS NECESSARY TO SOLVE MANY OF THE COMPLICATED PROBLEMS THAT ARE CONSTANTLY BEING ATTACKED.

cause such serious diseases as chestnut blight; Erwin F. Smith, who discovered that bacteria cause diseases in plants; Theobald Smith, who was in charge of the epoch-making cattle tick fever investigations; and Sewall Wright, whose work with inbred lines of guinea-pigs made notable contributions to animal genetics.

The Department is justly proud of its record as a great research organization, and the credit is due to such men as these and their coworkers They have left a permanent impress on the Department and exerted a strong influence on other, younger men. If we build still better things on the foundations laid since 1862, as we hope to do, it will be because the Department continues to attract the same kind of ability and the same kind of singleminded service to science.

The Extent of Agricultural Research

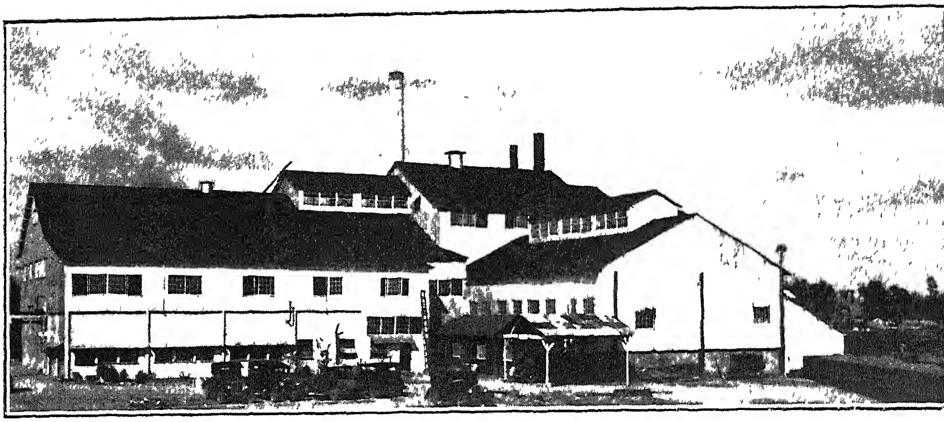
The research carried on in the Department of Agriculture not only vitally affects the interests of six to seven million American farm families; it also touches almost every individual in the country in one way or another. Most people think of the work of the Department as being concerned with the production of crops and live stock, but it is by no means exclusively that. There is a wide range of things that affect production or develop logically from it. The building and maintenance of roads; the conservation of soil fertility and the related prob-

lems of managing vast forest areas wisely, and conserving wild life; weather forecasting and study of the effects of weather, the refrigeration, storage, transportation and marketing of farm products; protection of consumers through meat inspection service and food and drug laws; the study of human nutrition so that food production may be linked with the physical welfare of the people of the country; testing and development of standards for various products used by farm families, for whom the government is a consulting service on innumerable problems—these and a great many other activities come within the scope of this Department Without research, these activities would be crude, fumbling and ineffective.

It is not surprising, then, that there are at least 6,700 specific lines of research going on in the Department of Agriculture at the present time Exactly how many there are it is impossible to say; there has never been any system for keeping an exact account of the details at a central place, but we are trying to work out such a system now so that at any time it will be possible to know the status of any line. Records are maintained on a broader basis, however, under a recently inaugurated Uniform Project System which groups all regular, continuing research activities into 672 "work projects," and these again into 180 different "financial projects," each covering a broad field of activity. I arrive at the figure of 6,700 specific lines of research because I know from their character that the 672 works projects on the average cover at least ten lines. In the near future we hope to set up "line projects" for each of these specific lines.

This, of course, is quite aside from regulatory and service activities. Although the Department has 15 bureaus, all of which carry on research of one kind or another—for example, Animal Industry, Entomology and Plant Quarantine, Plant Industry, Soil Conservation Service, Weather Bureau, Forest Service, Public Roads, Chemistry and Soils, Agricultural Engineering, Home Economics, Food and Drug Administration, Biological Survey, et cetera—the research activities often cut across strictly administrative lines and come under more than one bureau. This creates a real problem of overlapping, duplication of effort and assignment of responsibility. The Uniform Project System should give a sufficiently clean-cut picture at all times so that this problem may be minimized. But then the other danger must be avoided—the tendency to schedule and regiment research work too closely. To give research work enough freedom so that it is not stifled in any way, but not so much freedom that the scientist wanders all over the lot, is a nice task of administration

Then there is the problem of getting adequate facilities. Here we are duly grateful for emergency funds which have been made available during the past two years, outside the regular appropriations for the Department With these funds we have been able to provide new greenhouses and laboratories for fruit work, a laboratory for the study of farm wastes; one for the study of naval stores (primarily resin and turpentine); field stations for cotton breeding; better facilities for the study of spray residues; buildings and equipment for the study of animal diseases; added facilities for research in nutrition and in genetics and breeding; and housing for research workers located at field stations. The total emergency funds used for these purposes during the two years amounted to about $7,000,000. Much more could be spent, but the line must be drawn here between what is actually needed to do a job adequately, and what is desirable but still more or less in the nature of a luxury.



SWEETPOTATO STARCH FACTORY

AT LAUREL, MISSISSIPPI, OPERATED BY THE SWEETPOTATO GROWERS, INC., A COOPERATIVE GROUP OF FARMERS. RESEARCH BY THE DEPARTMENT LED DIRECTLY TO THE ESTABLISHMENT OF THIS PLANT

THE BANKHEAD-JONES ACT—A MAJOR STIMULUS

Now, as every scientist knows, one of the major afflictions of the research worker's life is the constant pressure from so-called practical men to get results By this the practical man usually means something that pays an immediate profit. It takes a considerable acquaintance with the scientific view-point and with the actual achievements of science to realize that the same standards can not possibly be made to apply here as are applied in business

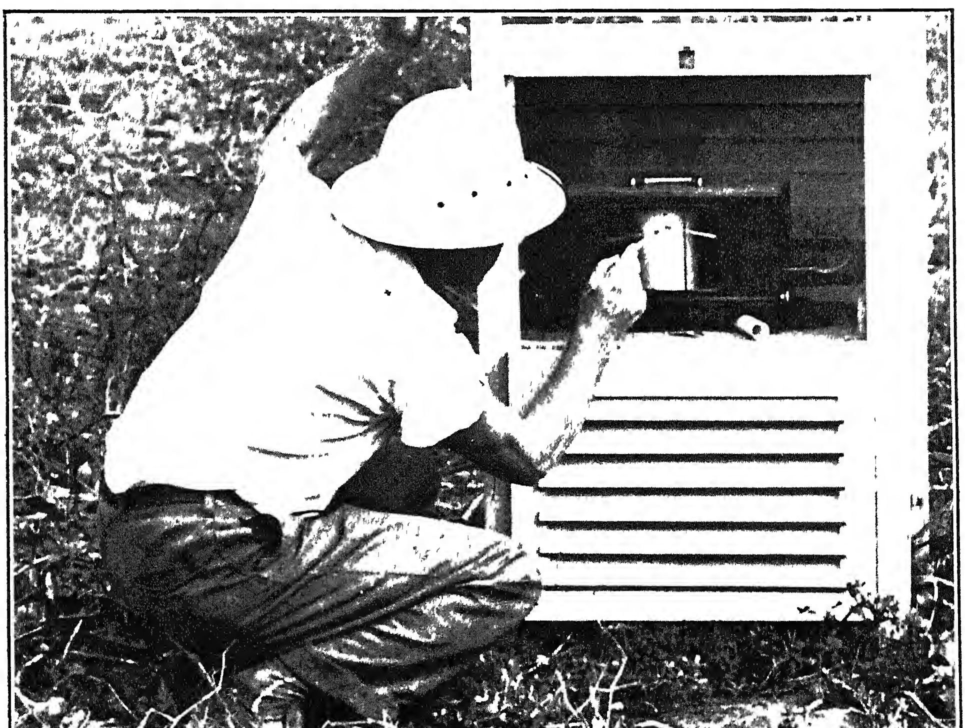
A familiar example is the development of the airplane by the Wrights The dramatic and sensational character of the achievement was far more obvious in that case than in most scientific research; but even so, there was a wide-spread feeling that while the contraption invented by the Wrights was interesting, it never could amount to anything from a practical standpoint. Judged by ordinary standards, the Wrights were just a pair of brilliant nuts who might have put their talents to much more practical use than loafing around for days at a time watching buzzards sail gracefully through the air. Out of this watching, however, the Wrights got facts and principles; and these facts and principles not only served as the foundation for a great new industry, but led to the conquest of a new element by man That could not have been done except by just such apparently dreamy and slightly insane goings-on The Wrights were not practical in the same sense that a man is when he puts a new gadget on the market and brings in a million dollars. They were merely super-practical.

So the research worker often feels like saying, "For heaven's sake, go away and don't bother me! Maybe what I am doing doesn't look to you as though it were leading anywhere—but fifty years from now you may have a different idea about it!"

This situation constantly arises in agricultural research also Fundamentally, the Department is concerned with making production better and more efficient, and insuring the preservation and adequate development of America's great agricultural resources—all for thoroughly practical reasons But to insist that everything done must have an immediate practical aim and that every dollar spent must return an immediate profit is to be blind to the real function of science In the long run, for example, it may be

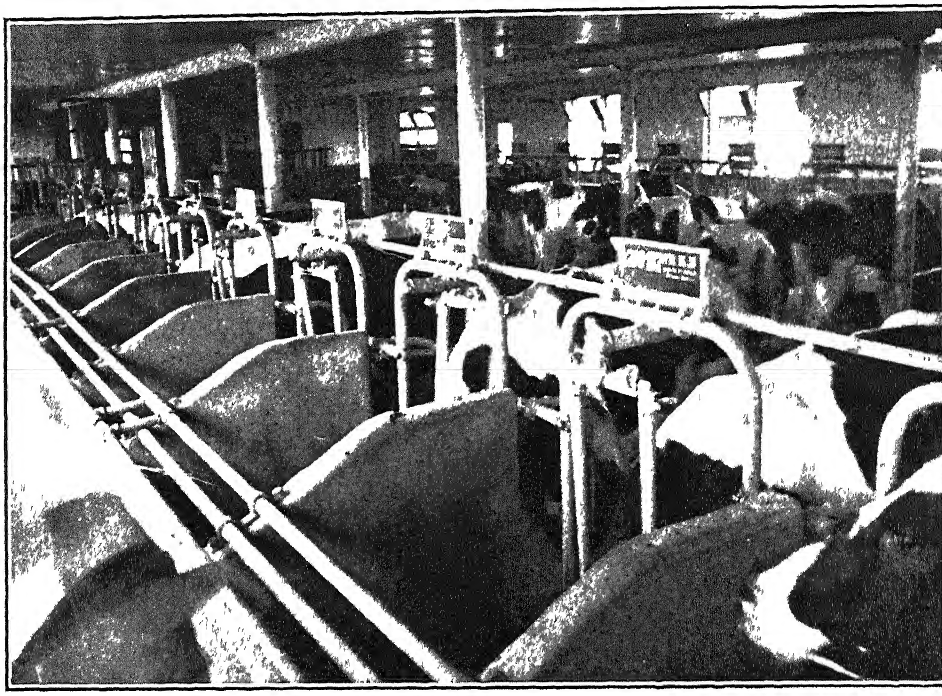
as worth while to develop an inbred line of dairy cows that break all records for low production as to be constantly trying to hammer away on better and better production Conceivably, the low-producing strain might more quickly turn up valuable information on the hereditary factors that influence milk production. Yet to the practical man, this seems like a hind-foremost way to go at the problem, and as far as he is concerned, he won't have his money spent on any such foolishness He can't quite understand why a research worker engaged on such a problem might feel a tingle in his spine and let out a yell of joy if he finally bred the world's absolutely most useless cow—and succeeded in finding out why

I don't say that that particular experiment would solve the problem of breeding consistently great milk producers But unless we are willing and able to make just such a basic approach to a problem whenever that approach seems to be called for, we might as well give up research And I would add that this basic approach is peculiarly the function of just such an organization as the Federal Department of Agriculture It can and should be relatively free of immediate pressures. It can and should concern itself with problems that affect the whole country, or great regions, and that are above the conflicting pull of purely local interests. It can and should carry on long-range, long-time projects that may take more than one generation to com-



RECORDING ATMOSPHERIC CONDITIONS

SCIENTISTS REQUIRE ACCURATE DATA ON ENVIRONMENTAL CONDITIONS IN ORDER TO INTERPRET ACCURATELY RESULTS IN THE FIELD.



MODERN HOUSING FOR COWS

DAIRY CATTLE BREEDERS SHOULD BE ABLE TO MAKE GREAT STRIDES IN IMPROVEMENT BECAUSE THEY HAVE TWO RELIABLE YARDSTICKS FOR PRODUCTION—MILK AND BUTTERFAT PRODUCTION.

plete, and that are too costly to come within the means of any unit smaller than a federal department

This, as a matter of fact, is what the Department of Agriculture tries to do. It has long had the national approach. The regional approach, which considers states in large groups based on homogeneous conditions and interests, is a newer development It has grown out of the pressing problems faced by agriculture during the depression—problems that necessitated the broadest possible planning, yet planning that would take regional differences into account.

Considered as a whole, then, agricultural research may be said to take in three things—national needs, regional needs and state or local needs. There is no sharp division, of course, and all three needs are likely to overlap, but the triple view-point is useful, particularly from the standpoint of administration.

It has been recognized in what is perhaps the biggest forward step yet taken to stimulate the kind of research I have been discussing in agricultural problems. I refer to the Bankhead-Jones Act, which passed the last Congress as H. R. 7160, appropriating funds, among other things, "for research into basic laws and principles relating to agriculture." Note the words, "basic laws and principles"—they are calculated to warm the heart of the scientist who often finds himself stumped at some vital point because too little is known about the basic laws and principles involved, and there is neither time nor money to follow through the difficult task of tracking them down. The funds allocated by this law are to be divided into three parts. 20 per cent. for

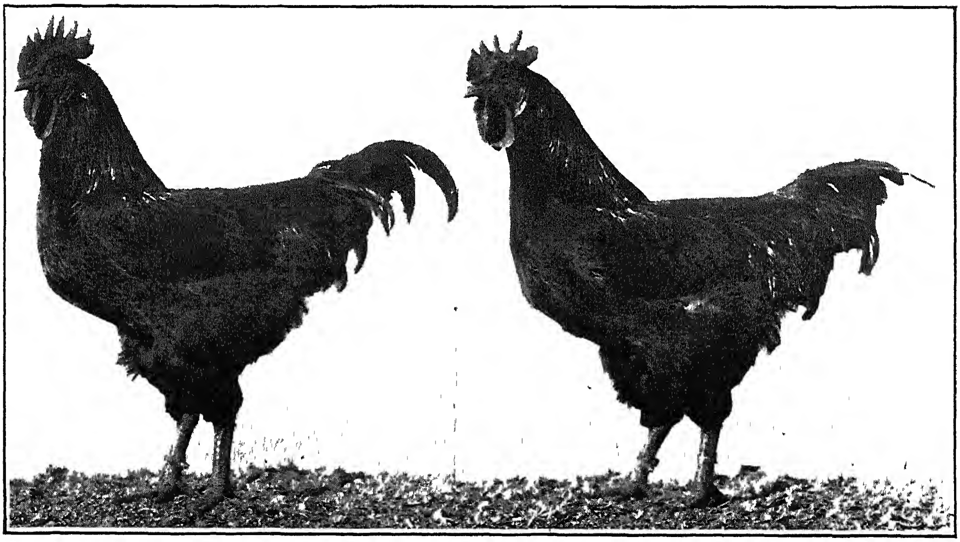
federal projects; 20 per cent. for regional projects, to be planned and carried forward under the direction of the Secretary of Agriculture; 60 per cent for state and local projects, to be carried on by the 48 state experiment stations, and the stations in Alaska, Hawaii and Puerto Rico

The use of these funds, then, will involve (1) research of a very broad kind by the Federal Government, including much really basic research; (2) setting up regional laboratories or research centers where the large regional problems—probably those suggested by the state experiment stations, who should have the most realistic understanding of what is needed—can be attacked; (3) continuance of experiment station work, which largely involves the application of the best available scientific methods and knowledge to a wide variety of local problems

It is not too much to say that the Bankhead-Jones Act is a milestone marking the most complete recognition we have yet had, first, of the prime necessity of research if we are to make progress; second, of the fact that to-day one of the major functions of government is to carry on this research, wherever it may lead, for the ultimate good of all the people. I realize that money and enthusiasm are not, by themselves, enough to ensure a worthwhile outcome; but I feel sure that this kind of approach, this kind of freedom to survey the whole field and follow any problem through relentlessly, and this forthright shouldering of a herculean task by the government—the only organization sufficiently big and sufficiently aloof to take it over—these things, I feel sure, are necessary if we are to get anywhere to-day

SUGGESTIONS FOR BASIC RESEARCH

Two kinds of research, scientific and economic, will be carried on under the Bankhead-Jones Act. These will cover (1) research in basic laws and principles, in the broadest sense; (2) research in the marketing of farm products, improved



FULL BROTHER RHODE ISLAND REDS

THEY LOOK ALIKE, BUT THE PROGENY TEST SHOWS THAT THEIR BREEDING WORTH IS ENTIRELY DIFFERENT. DAUGHTERS OF THE BIRD ON THE LEFT AVERAGED ONLY 160 EGGS EACH, WHILE DAUGHTERS OF THE BIRD ON THE RIGHT AVERAGED 206 EGGS.

methods of production and distribution, new uses for products and by-products, et cetera, (3) research relating to the conservation of land and water resources and their best development and use.

How significant a step this is the reader will realize if he looks over the following list. It is a partial list of research problems suggested by various research workers, bureaus and committees as suitable for attack under the first division of the Bankhead-Jones fund—that is, the 20 per cent assigned for basic research without restriction. Any scientific reader, I think, can not but have his imagination stirred merely by going over this list

Studies of Plant and Animal Genetics

- Comparative genetics and cytology of a polyploid series—wheat
- Development of a strain of dairy cattle genetically pure—(homozygous) for a low level of milk production as a basis for genetic studies on milk production factors
- Development of indexing techniques to be used in inheritance studies with meat and fiber producing animals
- Linkage of visible characters and endocrine physiology

Animal and Human Physiology

- Physiology of reproduction of domestic animals
- Measures of nutritional status
- Pharmacological and physiological effects of plant constituents
- Physiology of insects

Plant Physiology

- Possible occurrence of plant auximones and hormones and their role in reproduction and general plant physiology
- The mode of action of length of day as a factor in plant growth and development
- Some phases of the chemical photosynthesis of plant substances
- Drought resistance of forest and shade trees

Animal and Plant Pathology

- The interrelationship of virus diseases
- Plant viruses, their nature and properties
- Study of groups of plant parasitic fungi, their taxonomy, physiology, pathogenicity, etc.
- Diseases of insects

Vitamin Studies

- Vitamin requirements of farm animals
- Quantitative evaluation of vitamin effects
- Measures of nutritional status
- Some phases of chemical photosynthesis of plant substances

Enzyme Studies

- Chemistry of enzymes

Studies of Fats

- Nutritive value of butter fat
- Chemistry of rancidity
- Rancidity of fat

Studies of Trace (Rare) Elements

- Trace elements
- Trace elements in natural foods
- Role of the various chemical elements in plant growth with special reference to trace elements

Pharmacology and Chemotherapy

- Pharmacological and physiological effects of plant constituents
- Chemotherapy of animal diseases

Studies of Wood

- Wood substance, its chemical and physical structure and colloidal properties

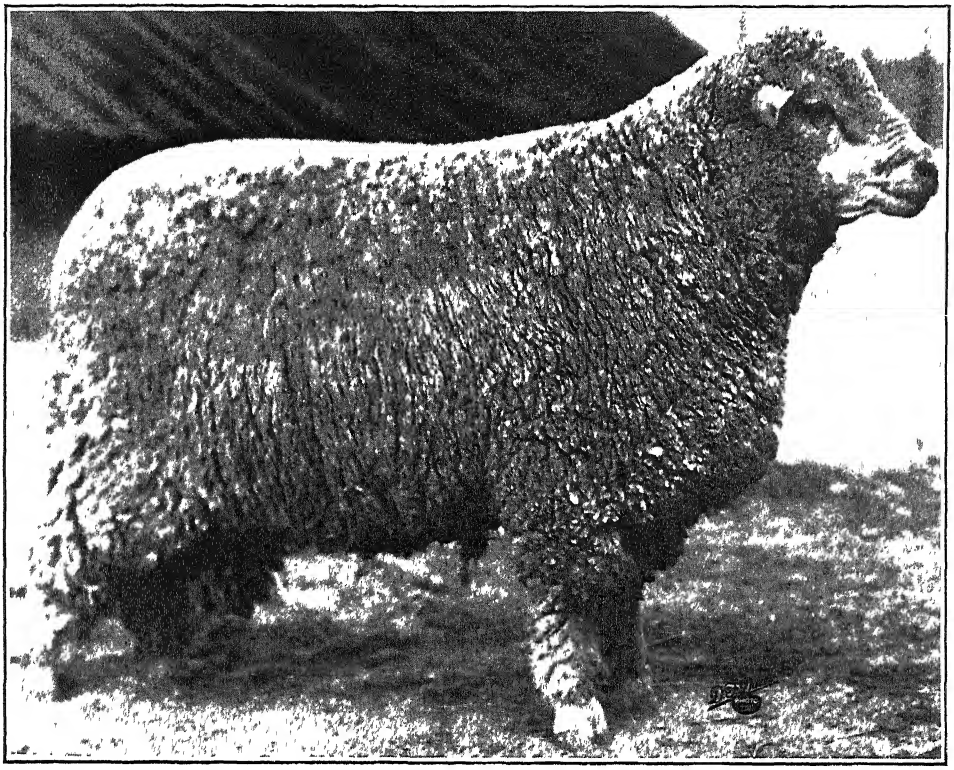
Agricultural Economics

- The actual as contrasted with the theoretical functioning of competition and bargaining in the marketing of farm products
- Interregional competition in the production and sale of farm products within the United States
- Land-use adjustments in farming areas

Weather Studies

- Development of a scientific basis for forecasting (well in advance) weather conditions during critical growing periods for important crop areas in the United States and competing countries
- Development of a scientific basis of forecasting (well in advance) crop yields per acre
- Investigation of climatic trends and their relation to crop yield trends
- Relations between antecedent pressure, temperature and rainfall in remote regions in the northern and southern hemispheres and temperature and rainfall in the United States

Innumerable problems, of course, might be suggested under the regional and state divisions. Under the regional division, for example, might come the development of improved varieties of



THE PRODUCT OF GENETICS

Columbia Ram developed by the Department by crossing Rambouillet ewes and Lincoln rams In eight years' comparison with purebred ewes of four breeds Columbias produced more wool and the lambs reached a greater weight at weaning time.

vegetables for the South; beef cattle improvement for the Southwest; research on the economic possibilities of power alcohol from corn, for the Corn Belt.

The last is suggestive of a much-needed approach that should now be possible We know that power alcohol can be made from corn or other farm products in the laboratory. But what are its commercial possibilities and limitations? This is a matter of controversy and opinion among experts Only experimental production on a commercial scale, and a sufficiently extended trial, can settle the questions involved. Similarly, in developing starch from sweet potatoes, it was necessary to set up and operate a plant of commercial size in order to put laboratory findings to a practical test Incidentally, in this case the experiment has met with signal success

A Survey of Research in Genetics

When it comes to giving an account of the present research work of the Department, the field is so large that I can at best pick out a few of the high spots, a few things that seem to me particularly interesting.

What comes into my head at once is genetics and breeding. Doubtless this is because I have been a corn breeder myself for more than 30 years. The joy and the thrill of the work are in my bones; the golfer making a hole in one gets only

KARAKUL SHEEP

RESEARCH ON LUSTER OF FIBER AND TIGHTNESS OF CURL HAVE DONE MUCH TO IMPROVE THE ECONOMIC STATUS OF THIS BREED.

a mild imitation of the kick the corn breeder gets when something clicks that he has been working on for years Corn breeding has bigger things ahead, but the degree of progress already made through the fine cooperation of numerous investigators may be judged from the fact that it is now necessary to divide the plant up on a genetic basis and hand out only one group of genes to each investigator. This division was made in 1928, when Dr. R. A. Emerson, of Cornell University, headed what is known as Maize Genetics Cooperation. Under this plan, the genes in corn are divided into their ten known linkage groups, and one man is responsible for research on each group, thus:

Group 1. P-br . . . Dr. R. A. Emerson, Agricultural Experiment Station, Ithaca, New York
Group 2. B-lg . . . G. W. Beadle, Institute of Technology, Pasadena, California
Group 3. a_1-Rg . . . R. A. Brink, Genetics Dept., University of Wisconsin, Madison, Wisconsin
Group 4. su-Tu . D F. Jones, Genetics Dept., Agricultural Experiment Station, New Haven, Connecticut
Group 5. pr-v . . . C. R Burnham, Agronomy Dept, University of West Virginia, Morgantown, West Virginia
Group 6. Y-Pl . . L. J. Stadler, Field Crops Dept, University of Missouri, Columbia, Missouri
Group 7 gl_1-ra . . M. T. Jenkins, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C
Group 8. j . . . G F Sprague, Agricultural Experiment Station, Columbia, Missouri
Group 9. c-wx . W. H Eyster, Botany Dept., Bucknell University, Lewisburg, Pennsylvania
Group 10 R-g_1 . E W. Lindstrom, Genetics Dept., Iowa State College, Ames, Iowa

Unpublished data are quickly exchanged among the investigators. Stocks of all genes and genetic testers are maintained and are available to all the workers in the field. To my mind, this maize genetics investigation stands out as a dis-

tinguished and suggestive example of close cooperation for a scientific end

The whole field of plant and animal genetics is at present getting intensive attention in the Department because we are in the throes of making up a Yearbook devoted entirely, in its textual matter, to that subject. The story of that effort in itself throws light on the work of the Department. Some time ago a committee was appointed, with O. E. Reed, chief of the Bureau of Dairy Industry, as chairman, to survey what was being done in this field Scientific readers need not be told that no division of biological science has come in for more intensive effort within the past 35 years than genetics and breeding; the rediscovery of Mendel's work at the turn of the century was an eye-opener comparable to the discovery of vitamins in the field of nutrition, and it stimulated an enormous amount of activity on a world-wide scale; a bibliography of agricultural genetics made by the Department library a few years ago listed over 1,000 titles on wheat alone. But where was all this work leading? Where do we stand? There seemed to be a need for surveying the entire field, summing up what has been accomplished, weighing the practical results, appraising and criticizing, picking out the weak spots, perhaps suggesting fruitful new possibilities. This was the task the genetics committee set for itself.

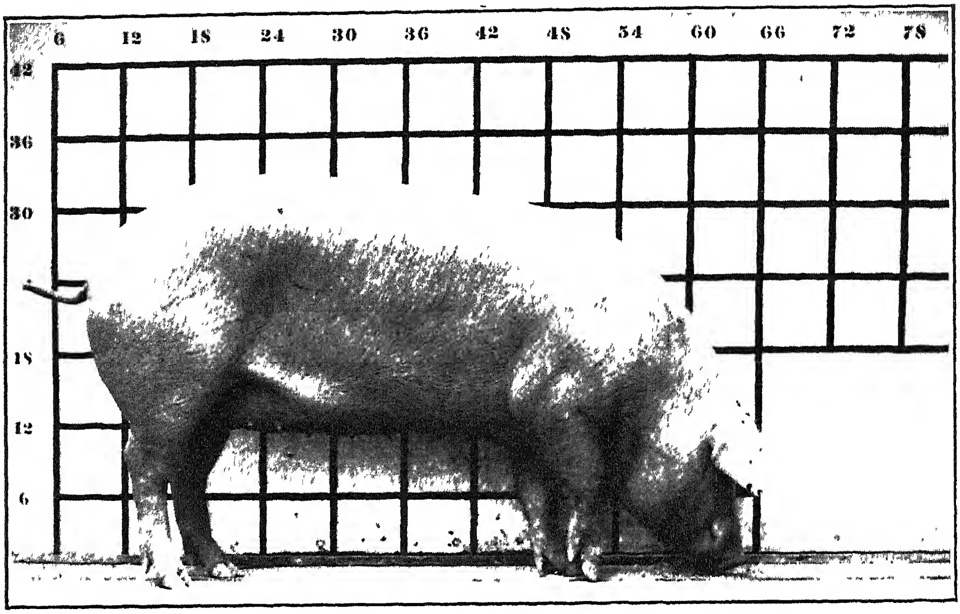
Admittedly it is no modest task Admittedly it can only be partially and imperfectly done; it is the kind of thing that calls for continuous effort by a group of men not only thoroughly well informed, but possessed of a peculiar ability to synthesize many lines of work and see the picture as a whole. Partial and imperfect as the results are, however, they turned out to be so interesting that it was decided to devote the 1936 Yearbook to them instead of to the usual miscellany of Department activities. There is good reason for this, in that nothing more vitally affects farmers than the breeding of improved plants and animals, more economical, more productive, better able to withstand the ravages of diseases that sweep like prairie fires through our close-packed modern plant and animal communities. At the same time, the genetic basis for these improvements and the methods employed are not commonly or widely understood It was felt, then, that such a Yearbook might have not only some practical value, but an educational value of a high order

As it worked out, the material shook down into two parts. There is first a running account and discussion of genetics and breeding work, second, a survey and actual listing of superior germ plasm in existence for the various classes of plants and live stock discussed. In the 1936 Yearbook there is room for only 19 classes, but these include all the major crops and animals, the wheel horses of agriculture It is hoped that the 1937 Yearbook may complete the job by covering a wide variety of plants and animals that are economically not quite so important, but perhaps of even wider interest.

Agricultural Aristocrats

These lists of superior germ plasm, compiled from material gathered not only in the United States but, in so far as possible, from all over the world, should constitute a sort of social register or Almanac de Gotha of agricultural aristocrats. (But this aristocracy is based on actual merit, not on name.) The lists will show where superior breeding material is available, and tell concisely why it is superior.

This is where the critical value of such a task comes in In making, or trying to make, a survey of superior germ plasm in live stock, it was found that for certain broad classes there is little or no material that can be actually considered superior There are strains that have



A DANISH LANDRACE GILT

ELEVEN MONTHS OLD, IN THE RECENT IMPORTATIONS DESIGNED TO IMPROVE THE MEAT QUALITY OF SWINE. THE LENGTH AND SMOOTHNESS OF SIDE AND DEVELOPMENT OF HAM ARE ESPECIALLY NOTEWORTHY

become famous, that are in wide demand and that command a premium on the breeding market. But when it comes to appraising these strains from the standpoint of superiority in characters that really matter, economically or practically, we find that we are standing on very unsure ground In the first place, there is little in the way of standards by which to measure this kind of superiority, which is the only kind that should count. In the second place, such standards as do exist are almost entirely based on conformation, color, type and other show points that make a pretty animal, but not necessarily a useful one. Yet these show points, along with pedigrees, are the ones that guide the breeder, and they are so firmly embedded in tradition that we have come to associate them with merit—which is very much like saying that people with lantern jaws or a prominent nose or royal ancestors belong *ipso facto* to a superior race.

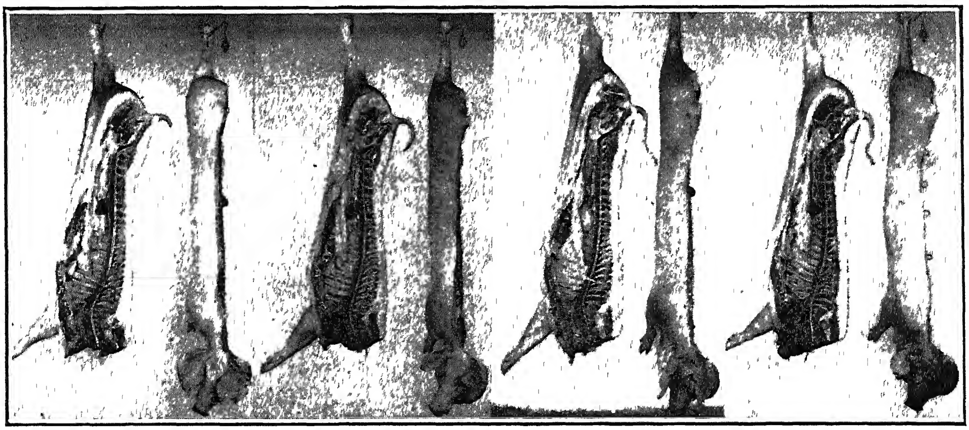
The reasons for this situation, which exists in most live-stock breeding, with the partial exception of dairy cattle and chickens, are too complex to analyze here They include not only lack of genuinely useful standards and reliance on standards that are superficial if not misleading, but also the cost and the difficulty of experimentation with the larger animals, and the baffling complexity of the genetic factors involved. The net result of all these influences is that animal breeding has not advanced at anything like the pace set in plant breeding

This is all very well; it may be said that the situation is inevitable. But analysis shows that very little is being done in the way of making a vigorous and direct effort to break the jam. Certain logical possibilities for progress are rather widely accepted by forward-looking animal geneticists, but there is doubt and hesitation in trying these possibilities.

The conclusion reached in the analysis presented in the Yearbook is that animal breeding may be said to stand at the crossroads If it follows one road, it will become a static art. The other road has at least the possibility of leading to progress. What is involved in following this second road is discussed at some length. The road can not be definitely mapped at the present time, but it is hoped that the discussion will show the urgent need to explore it. Four groups have a vital interest in the improvement of farm live stock: the consuming public (including such groups as the meat packers), the farmer-producers, the professional breeders and the scientists. Logically, the scientists should be the ones to lead the way.

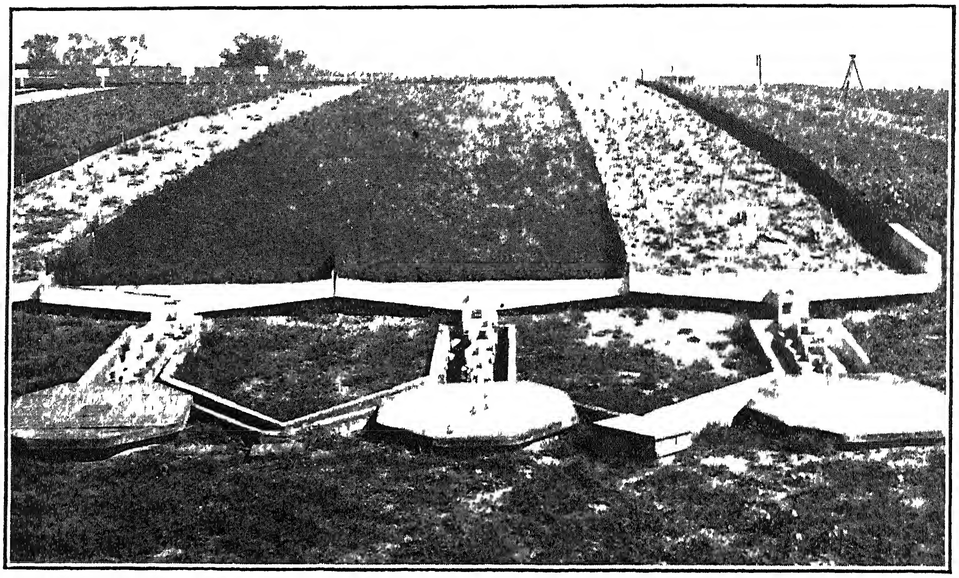
Four recent importations of live stock by the Department of Agriculture are interesting in this connection Two years ago we brought to this country strains of the famous Danish Landrace and Yorkshire swine, and recently we have made importations of Red Danish cattle and Hungarian Nonius horses (and incidentally of Hungarian sheep dogs, to be used in breeding experiments) Each of these strains is important for characteristics of economic value, the Landrace and Yorkshire swine, for example, have been developed in Denmark for efficient production of high quality bacon, particularly the type known commercially as Wiltshire sides Experiments will be made with a view to transferring some of these desirable characteristics to our own breeds

This is a common procedure in plant breeding. Even in plants that have no commercial value in themselves, the breeder often finds characters greatly needed in commercial varieties By proper breeding methods, he can transfer these characters to the commercial varieties, often without losing any of the desirable traits possessed by the latter. Thus every smooth-awned barley grown in America to-day got this characteristic



CARCASSES FROM FOUR HOGS IN BREEDING TRIALS

FROM LEFT TO RIGHT THEY ARE DANISH LANDRACE SOW, DANISH LANDRACE BARROW, POLAND CHINA × LANDRACE BARROW, AND INBRED CHESTER WHITE SOW. TO DETERMINE THE SUPERIORITY OF THESE ANIMALS CAREFUL DATA ON AVERAGE DAILY GAIN, DRESSING PERCENTAGE, CARCASS LENGTH, PLUMPNESS OF HAM AND CARCASS GRADE WERE RECORDED. FOR EXAMPLE, THE DANISH LANDRACE BARROW MADE AN AVERAGE DAILY GAIN OF 1 86 POUNDS, THE DANISH LANDRACE SOW SHOWED A PLUMPNESS OF HAM OF 186, AS COMPARED TO 124, WHICH IS THE AVERAGE OF 500 HOGS OF AMERICAN BREEDS; AND THE INBRED CHESTER WHITE SOW HAD A CARCASS GRADE OF PRIME MINUS. THIS TYPE OF WORK IS ESSENTIAL FOR IMPROVING OUR MEAT CLASSES OF LIVE STOCK.



MEASURING SOIL EROSION

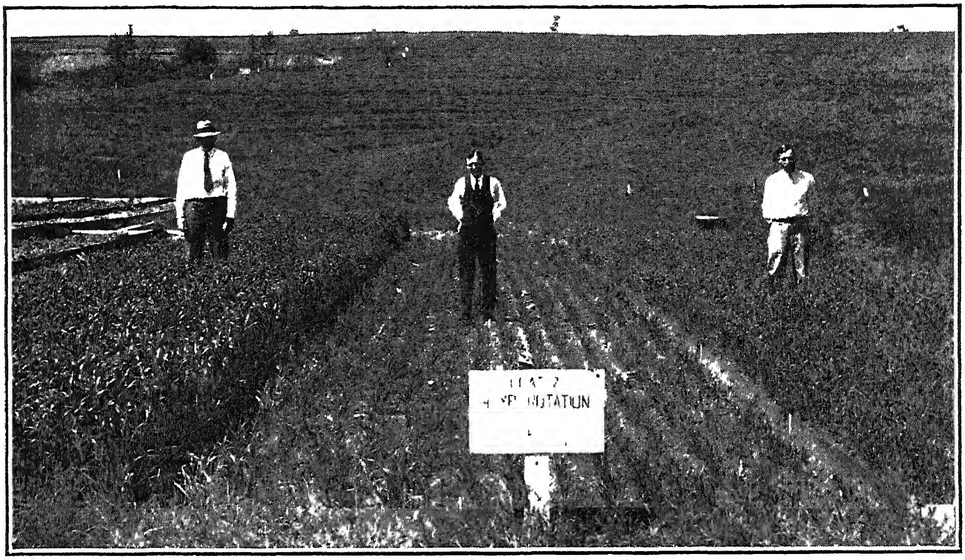
DEVICE FOR MEASURING SOIL LOSS AND WATER RUN-OFF IN CONNECTION WITH STUDIES OF SOIL CONSERVATION SERVICE AT BETHANY, MISSOURI.

from an obscure strain imported from Russia.

A dip into one of the plant chapters of the 1936 Yearbook will show some of the results of the survey in this field. In the case of wheat, for example, the history of modern wheat breeding is presented in some detail, and the present research work being done in America, and in every foreign country where wheat is at all prominent, is summarized. A report sent in for the survey from Russia, for example, indicates that as a result of systematic collection work, Russian scientists have assembled 31,000 different wheat specimens from all over the world, and the claim is made that, as a result, the number of known botanical varieties—as distinct from agronomic varieties—must now be extended to 650, whereas only 195 botanical varieties are listed in the most complete previous monograph on wheat, prepared in England in 1921.

To help prospective breeders, the names and addresses of the leading workers in each country are given, and there is a similar, more complete directory for each state in the United States. For the United States, all important projects now going on at each experiment station are included. Thus, the information for Minnesota is summarized as indicated in Table I on page 24.

It will be seen that the material in the genetics survey should be of use to those engaged professionally in this field. That, however, is not its only purpose. The primary purpose, in fact, is to present a broad picture, understandable to those vitally interested in American agriculture, of one of the most fascinating and dynamic branches of biological science, and one that is making very great contributions to the well-being of the farmer. The picture should be sufficiently simple so that the lay reader will get an intelligent grasp of what this intensive activity is all about, and see its failures and shortcomings as well as its achievements.



REJUVENATING ERODED SOIL

NOTE GROWTH OF OATS ON NON-ERODED SOIL AT THE LEFT AS COMPARED TO DESURFACED PLOT IN THE CENTER AND DESURFACED AND FERTILIZED PLOT ON THE RIGHT. THESE STUDIES OF SOIL CONSERVATION SHOW THE EFFECT OF EROSION AND METHODS OF "BRINGING BACK ERODED SOIL."

My personal hope is that the account will stimulate many more amateurs to do some experimenting of their own Over and over again, in the various chapters, the names of amateurs crop up among those who have made notable contributions to plant or animal breeding Some of these amateurs were not even farmers—but they got the genetic bug, a bug whose bite produces a benign fever calculated to make a man forget his troubles.

A single kernel of wheat may produce 2,000 progeny by the next generation. If that kernel was the hybrid product of a cross, the progeny in the segregating generation may show hundreds of new combinations of characters. And those hundreds of combinations can be produced in a back yard There are possibilities here that might occupy a man's spare time for years.

Research and Soil Conservation

Four other broad examples may be given here of the research activities of the Department as they tie in with the work of various divisions and bureaus Three of these deal with the three large conservation bureaus

First, Soil Conservation: Conserving the productivity of our agricultural lands involves a whole series of complex problems. The first thing is to safeguard the physical body of the soil Renewal of plant nutrients by the application of fertilizers and through cultural practices is worth while only if the integrity of the soil is maintained. When the soil itself is lost through erosion by wind or water, continued cropping becomes self-destructive or suicidal.

The Erosion Reconnaissance made by the Soil Conservation Service in 1934 showed that wastage of soil resources within the short period of occupation of our country by the American people has been proceeding at a disquieting rate. An area approximately the size of the State of Kansas has been ruined for further cultivation by gullying of cultivated fields. Possible uses left for such

FOREST FIRE RESEARCH

OBSERVATIONS ON THE BEHAVIOR OF FOREST FIRES UNDER CAREFULLY MEASURED CONDITIONS LEAD TO MORE EFFICIENT PROTECTION.

devastated lands are restricted to rough pasture or protection forests. It was discovered, furthermore, that original soil profiles have been truncated by sheet erosion over great areas Fully 190 million acres have lost more than half of the original topsoil, chiefly by water erosion, and about 9 million acres have been practically ruined for further cultivation by the loss of wind-blown soil, or by the accumulation of hummocks because of wind erosion.

It was found that the good lands of the nation have been occupied and that for the most part they have been cleared and cultivated. Only 75 million acres of the 365 million that have been used for food and fiber production were found to be level and little subject to erosion The basic fact, then, is that agricultural production must depend chiefly upon the cultivation of sloping lands, and these are the lands that are subject to the ravages of water erosion.

Soil erosion was recognized by the National Resources Board in its report to the President in 1934 as a physical crisis in land use. The rate of soil wastage under modern agricultural technique calls for the development of control measures more promptly than they can be developed by the tedious trial and error method of former times. Only systematic experimental investigations into the character of the factors involved, and into methods for the prevention and control of erosion, will enable us to find a prompt solution to the problem involved in the sustained use of cultivated lands. In short, the principles of scientific research must be applied here exactly as in other important problems confronting agriculture.

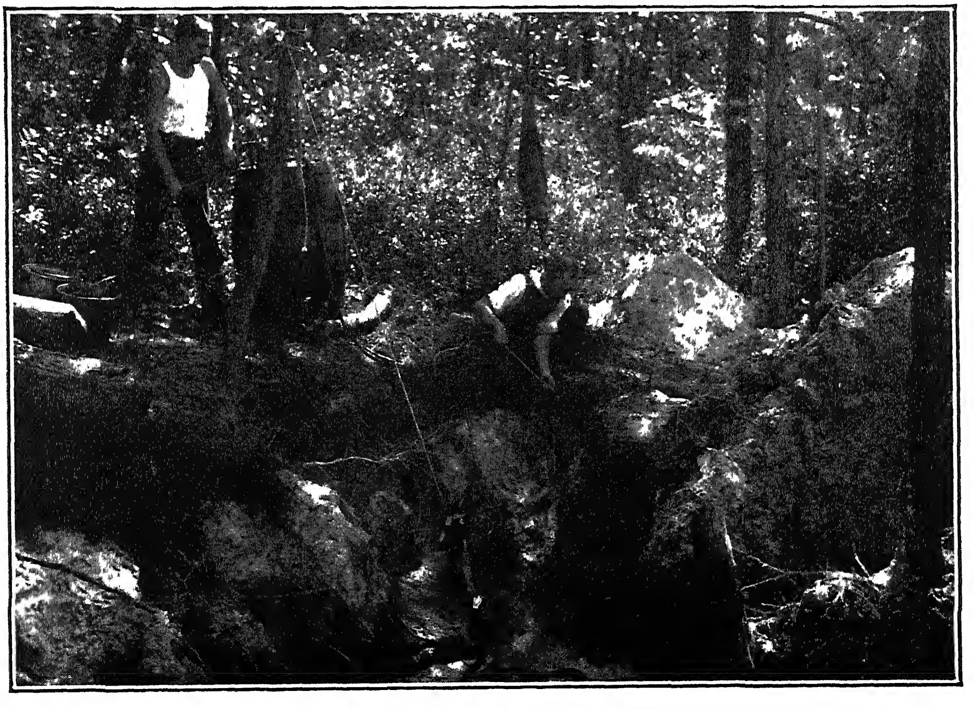
Research in erosion control requires the synthesis of a number of divisions of science, since erosion is a complex phenomenon. Its character must be fully identified and its trends charted. As a geologic process, erosion is older than the most ancient sedimentary rocks; it has

sculptured landscapes and supplied materials for vast sedimentary deposits since Proterozoic times. Yet within regions enjoying a climate that supports a complete coverage of vegetation, this geologic erosion has not normally proceeded at rates faster than soil formation. Under such conditions, soils and natural vegetation have developed through thousands of years, each depending on the other On the other hand, when the natural coverage of vegetation is removed by whatever cause, as by clearing for cultivation, the soils are bared, as they had not been before, to the direct action of wind and flowing water Erosion of an entirely different order, man-made and accelerated, is thus introduced by agricultural operations This kind of erosion proceeds at rates much faster than soil formation, and the ultimate destruction of the soil is inevitable.

Acceleration of erosion by flowing water arises from reduced absorption of rain by the soil, and it occurs chiefly on sloping lands Rates of erosion are dependent on a wide range of factors, and they vary from field to field, from slope to slope and from region to region. Climate, soil characteristics, slope gradients and methods of land use all have an effect. All these elements must be studied and evaluated if we are to develop measures for sustained land use.

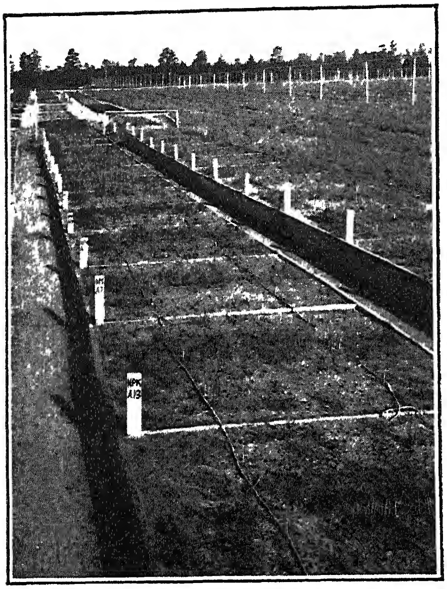
Two major types of investigations, exploratory and experimental, are included in the necessary research

Exploratory investigations comprise surveys and preliminary experimentation to discover the nature and extent of erosion wastage and its effects on eroded



STUDIES OF ROOT SYSTEMS

AID IN SELECTION OF PROPER SPECIES TO FAVOR IN SILVICULTURE AND PLANTING.



FOREST TREE NURSERY

FERTILIZER AND NUTRITION STUDIES IN FOREST TREE NURSERIES POINT THE WAY TO BETTER SURVIVAL AND GROWTH OF PLANTATIONS.

fields, stream channels, storage reservoirs and flood control. These investigations include such erosion reconnaissances as the one made in 1934 by the Soil Conservation Service in cooperation with the state experiment stations; detailed surveys of the nature and effect of erosion on agricultural communities; and surveys of the condition of the storage reservoirs of the nation, such as the one that has been under way for a year.

Experimental as distinct from exploratory investigations involve thorough analysis of the factors of soil conservation region by region, and an experimental evaluation of the factors concerned in soil and water losses under various conditions. They also involve actual experimenting with practices and measures for prevention and control. A beginning has been made in the 10 erosion experiment stations established in 1929. Studies carried on in each region disclosed startling losses in eroded soil

TABLE 1

MINNESOTA, Experiment Station, University Farm, St. Paul

WHEAT BREEDERS.

Early workers:	W. M. Hays, Andrew Boss, A C Arny, C P Bull, E. M Freeman, A G Johnson, J. H Parker, O. S. Aamodt
Present workers.	H K Hayes, E. C. Stakman, E R. Ausemus, R H. Bamburg

BREEDING METHODS.

Commercial Varieties	*Promising New Strains*
Introduction (1888–1935)	*Hybridization* ·
Marquis, Ceres.	*Winter*
Selection (1902–1935).	Minturki × Marquis Minn. 2616, C. I. 11501
Haynes Bluestem Minn 169 (1899), Glyndon Fife Minn. 163, (1899), Mindum, (1917)	Minard × Minhardi Minn. 2313, C. I. 11656
Hybridization (1902–1935):	*Spring*
Hard Red Winter Minturki (1917)	Double-cross Minn. 2315, C. I. 10020
Soft Red Winter Minhardi (1917)	H-44 × Marquis Minn. 2631, C. I. 11643
Hard Red Spring Marquillo (1929) Thatcher (1934)	

Present work Winter wheat—Minhardi, Minturki and Minard, crossed together and with Marquis, Hope and H-44 to obtain hardy winter varieties improved in quality and resistant to stem rust.

Spring wheat · Marquillo, Thatcher and other hybrid selections crossed with Hope and H-44 to obtain greater resistance to stem rust, leaf rust and bunt.

and in water as surface runoff. Topsoils under clean-tilled crops were found to be wasting away so that they were lost completely within less than a generation. Crops in usual rotations reduced this rate of soil loss, but they have not been found adequate to safeguard soils on sloping lands for continued cultivation It became apparent that there is a maximum slope gradient which varies with soil type and that any cultivation on gradients greater than this is unsafe. Close-grow-

ing crops and forage crops gave the greatest protection against erosion

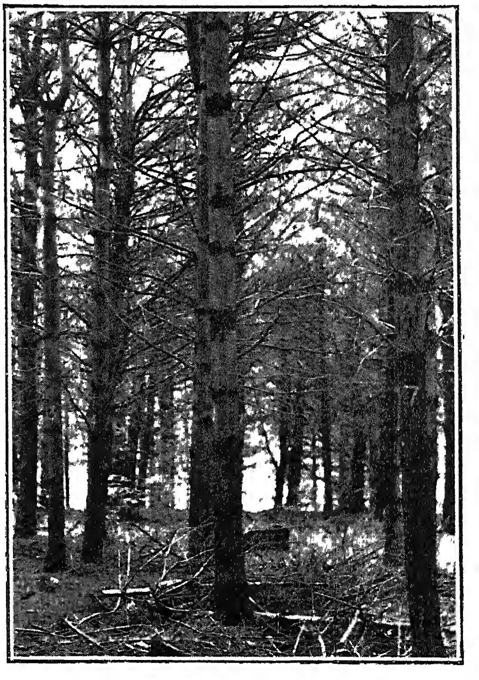
Where Action Must Precede Research

Such facts must be established for each important agricultural region as a necessary preliminary to researches in methods of prevention and control The research worker finds that he must take into account regional variations in climate, slope, soil type, vegetation and faunal responses The study of prevention in regional research centers include agronomic measures (rotations, strip cropping), cultural practices (contour cultivation), and engineering structures (terraces, check dams), and their adaptability and practical application to the several farming regions of the nation. The perfect solution might be level terracing, such as was practiced by the Incas, but it is at least open to doubt whether modern Americans would ever be ready for that

It would be national folly to let our good lands continue to be wasted when measures for their protection may be discovered and applied. As long as major crop production must be on sloping lands, the objective of the Department of Agriculture, in cooperation with state and other agencies, is to establish methods and practices that will make sustained cultivation safe.

Along with the task of saving the good land of the nation from continued wastage goes the task of rehabilitating and rebuilding soils that have been severely damaged by sheet erosion, reclaiming areas ruined for further cultivation by gully erosion, and restoring vegetation on those parts of the great plains that have been badly damaged by wind erosion. Vegetation is man's chief ally in such tasks. Only a beginning has been made in the selection and use of suitable plants and combinations of plants, native and exotic, for this purpose.

In this brief outline I have attempted only to point out some of the factors involved in soil conservation research—chiefly those factors about which too little is now known. But enough is known to stop many suicidal practices, based on short-sightedness, haste, ignorance, selfishness and economic pressure. There is an intense practical need to stop many of these practices immediately, long before everything is known that will be known about soil conservation. Not everything is known about icebergs, but it is certain that a ship has to be put in reverse when an iceberg looms up ahead This is what is now being done in agriculture In the Agricultural Adjustment program, major emphasis is laid on Soil Conservation and better use of land, and many of the features of the program are aimed directly at the elimination of wasteful practices. These features, I think, are here to stay. As fast as science makes available new knowledge and



MODERN FORESTRY

Thinning and pruning experiments determine the possibilities of improving the quantity and quality of forest products.

sound techniques, they too will be put to practical use Meanwhile, I am glad to say, American farmers show a spontaneous interest in the soil conservation aspects of the program, and a desire to stop practices that lead to the deadly waste they see under their own eyes

Forest Service Studies All Factors—Biological, Physical, Economic

The forest research program of the Department, centered largely in the Forest Service, is another example of research designed to supply the fundamental technical knowledge without which an objective can not be worked out intelligently or have anything approaching permanence

The handling of forest lands and the manufacture and utilization of forest products are intimately associated with fundamental problems of social and economic rehabilitation. This requires the application of the idea of timber cropping for sustained yield

The objective of the Department's activities in the forestry field is to facilitate this rehabilitation, and to bring about a situation under which all the forest land in the United States will make its maximum contribution to economic and social welfare. In this the whole range of biological, physical and economic factors are directly concerned—biological in the growing of the forest crop, physical in its manufacture and utilization and economic in stabilizing the entire forestry enterprise and the communities dependent on it

Put in another way, this research program is designed to supply the technical foundation for the administration of the national forests, coordinating the submarginal land program of the AAA with the acquisition of public forest lands; cooperative development of state forestry; stimulation of forestry on private lands; and the intelligent use of forest, brush and range cover in watershed protection.

This is an enormous and intricate field affecting directly more than one third of the land area of the United States, a thousand tree species; a wide variety of forest type combinations; climatic variations from the semi-desert to the heavy rainfall of the fog belt, from the tropics to the sub-alpine, and from sea level to 11,000 feet. The soil variety and producing capacity are equally varied, as are the social and economic problems involved.

The forest research of the Department is organized to supply the basis for reforestation; for improving, through plant breeding and cultural practises, the quantity and quality of timber growth; for protecting and maintaining

NATURAL MARSHLAND MOST PRODUCTIVE

Extended research by the Biological Survey covering many million acres of marshland have shown conclusively that the natural plant food products devoted to production of waterfowl, aquatic fur-bearers and other wildlife usually greatly exceed in value the agricultural crops that can be produced when such areas are drained.

forest cover where it is needed for recreation, watershed protection or wildlife; for investigating the replanting or revegetation of depleted ranges and the intelligent handling of forest and other range lands, with a view to maximum forage production consistent with soil protection and the prevention of erosion; for reducing waste, increasing the utility and satisfaction of forest products to the consumer, and creating new and useful products from wood; for dealing with the financial aspects involved in forest land management, the production and utilization of forest products, present and potential forest-producing capacity, and prospective forest requirements; and for investigating the effect of forest cover and wild-land vegetation on water supply, erosion prevention and climatic and environmental conditions generally.

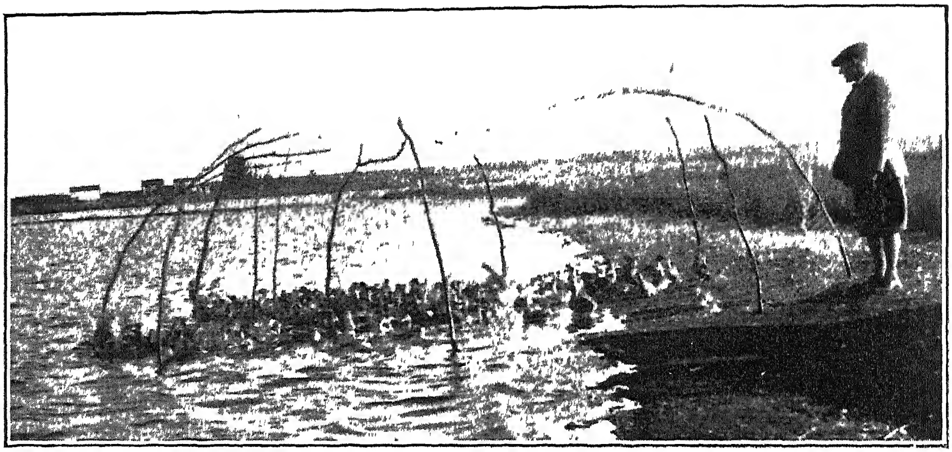
For efficient administration and correlation, this research work is carried on by 12 regional forest experiment stations, some located so as to collaborate closely with land-grant colleges, and by the Forest Products Laboratory, a national institution associated with the University of Wisconsin where forest products research is centered

Since forestry deals entirely with growing plants, many of its detailed problems are exactly like those met with elsewhere in agriculture—problems in disease and insect control, plant breeding, adaptability of plant crops to soil and climate, and so on. Interesting in this connection is the work at the Eddy Tree Breeding Institute at Placerville, California, recently taken over by the Department. Here an experiment in breeding trees with superior germ plasm was started by private initiative in 1926. It is an excellent example of long-time research that is bound to give results; and the fact that it could not be continued under private auspices is another instance of the fact that such long-time projects can hardly be carried on except by governmental agencies.

AN IMPORTANT FUR-BEARER

RESEARCH HAS DEFINITELY DETERMINED THAT THE NORMAL BREEDING SEASON IN MARTENS OCCURS DURING THE SUMMER MONTHS, USUALLY BETWEEN THE MIDDLE OF JULY AND THE THIRD WEEK IN AUGUST, AND THAT THE GESTATION PERIOD RANGES FROM 8½ TO 9 MONTHS (259 TO 275 DAYS) INSTEAD OF 60 TO 102 DAYS, AS HAS BEEN HERETOFORE BELIEVED.

Already the information gathered at this breeding nursery has had a marked effect on timber practises. The Forest Service has changed its ideas in regard to the pine—ideas which should furnish the seed stock for replanting these areas. Also, some attractive new types of tree hybrids have been developed. For example, the Monterey pine, possibly the fastest growing of any of the pines in its early youth, is not very resistant to frost and is therefore limited in its use. However, crosses between the Monterey and the Knob-cone, a type found on scrubby



MIGRATORY WATERFOWL TRAPPED FOR BANDING PURPOSES

RESEARCH BY MEANS OF NUMBERED BANDS IS FURNISHING THE VITAL INFORMATION NECESSARY FOR THE PROPER CONSERVATION AND ADMINISTRATION OF THIS WILDLIFE RESOURCE.

land and extremely frost-resistant, have produced new types which possess the desirable characteristics of both parents, that is, they are both frost-resistant and fast-growing.

New Program in Biological Survey

Wide-spread interest is being shown in the plans of the Biological Survey to set up, in cooperation with the land-grant colleges and other agencies, a far-sighted program in the important field of wildlife restoration and maintenance. The seemingly limitless wildlife resources of North America have been dissipated, despoiled of suitable habitat and slaughtered as the settlement and development of the country progressed. Such effort as there has been in the direction of improving conditions has been handicapped and rendered largely ineffective by lack of biological information and knowledge of the correct principles to apply in practise. As a result, wildlife conditions have gone steadily from bad to worse in recent years

The new program is designed to meet these issues squarely and effectively. Careful study has been made of the major ecological regions of the United States as a basis for selecting locations. The program of research, demonstration and education will be tied in with 9 land-grant colleges, including their agricultural experiment stations and extension services. The active cooperation of state game departments or conservation commissions has been enlisted, and the recently organized American Wildlife Institute, a continental agency devoted to wildlife restoration, is giving financial aid. Problems representing the more important wildlife species of game and fur-bearers are being selected for research, which will be conducted by experts assigned by the Biological Survey and the colleges, including picked graduate students who will be given theoretical training, guidance in fact-finding and research and practical experience in wildlife management.

Research and practical field demonstrations will be conducted on representative areas of federal, state and privately owned lands. The demonstrations will be based on the research findings applied to improved land and wildlife management

practise and will thus enable land owners and public officials responsible for land use to observe results in actual field operations In connection with this research and demonstration program, the colleges will give undergraduate courses of instruction leading to degrees in the wildlife management field Extension activities will bring essential features to public attention and encourage land owners and 4-H Club workers to make use of the available information and to adopt sound wildlife production practises in their use of land, marsh and water areas

Long-Range Weather Forecasting

One of the major services conducted by the Department of Agriculture is weather forecasting The fact that weather can not be forecast long in advance is a major handicap in farming and many other operations. Nearly everybody is interested in long-range forecasting, but so far there has been little in the way of tangible results

Apparently there are several approaches to the problem, and various institutions are working at it from different angles—oceanography, solar radiation, air mass analysis, electromagnetic phenomena, the study of conditions in the polar regions, *et cetera*. Few scientific problems are more truly worthy of a vigorous and concerted attack by every agency that can make any genuine contribution.

To supplement the work that is being done elsewhere, the Department of Agriculture is doing two things.

(1) The Weather Bureau has compiled extensive records from 60 stations throughout the world to see whether variations at any of these stations precede, by one or two or three seasons, variations in any one or more of 12 districts in the United States. These records go back 60 to 100 years, and the effort is to see whether they fall in patterns that might give a clue to conditions that might be expected the following year, or even farther ahead than that Even if the results are negative, a thorough examination of this field should make it unnecessary for other investigators to go over the same ground.

(2) In the Bureau of Agricultural Economics, in cooperation with the Weather Bureau, a research project is being carried out to determine the possible effect of solar and planetary influences on weather, and to study cycles and lag-correlation in temperature and rainfall in the various states, with special reference to crop forecasting. Once these possibilities have been explored, the Department will be in a position to take up other suggestions

SCIENCE ADVISORY SERVICE TO THE GOVERNMENT

By Dr. KARL T. COMPTON

PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND CHAIRMAN OF THE SCIENCE ADVISORY BOARD[1]

In his book, "The Advance of Science," Mr Watson Davis has estimated the total national expenditure for work in science by government, industry, foundations and universities combined to be of the order of one hundred million dollars per year. Of this amount, roughly one third appears in the budgets of the scientific bureaus of the Federal Government, and roughly one third each is expended by universities and industries. Because of the difficulties in defining scientific work and of securing data on comparable bases, these estimates can only be considered to represent the orders of magnitude. They do, however, give an idea of the dollar value which the general public places upon the scientific work which forms a basis for its future welfare

In comparison with the total national budget, the expenditures for science are an exceedingly small item Scientific work of the government accounts for considerably less than half of 1 per cent of the Federal budget. The total national expenditure for science amounts to something like the cost of a half-dozen warships Altogether it amounts to about one cent out of every five dollars of the total national income. On the other hand, it is this scientific work which has brought about our present standard of living and which is basic to our opportunities for future betterment in health, industrial and agricultural prosperity, and in avoiding those misfortunes which will otherwise inevitably beset us with the exhaustion of certain natural resources.

In this public service of science and scientists, the government, of necessity, plays a rôle whose importance to the country is far greater than the proportionate amount of interest and support which it customarily receives from the occupants of political office. Fortunately, however, there have been, from time to time, public administrators of great vision who have realized the immediate services and ultimate values of scientific work and have brought about the establishment of various scientific bureaus. Fortunately also these bureaus have attracted a great group of able and loyal public servants without whose cooperative effort a great and complex country like ours would utterly fail to function. They advise us regarding the weather, maintain consistency in our technical and manufacturing standards, aid and advise the farmer, maintain the safety and improve the quality of transportation, maintain our health and in innumerable ways aid every group of our population. To quote from the second annual report of the Science Advisory Board.

> In a democracy like ours, designed to safeguard personal liberty and to stimulate individual initiative with the framework of "general welfare," there is no need for the Government to embark upon comprehensive programs in pure science, invention or industrial development. There are, however, numerous scientific services of such wide scope and universal utility that no agency except the Government is competent

[1] In this article the author draws freely from the experience and studies of the Science Advisory Board and the ideas of his colleagues, but he takes personal responsibility for such opinions as are here expressed in regard to the organization and functioning of a Science Advisory Service to Government.

adequately to handle them There are other scientific services which are essentially supplementary to non-scientific governmental activities. There are also fields of scientific or technical development which hold evident promise of benefiting the public but which are not proper or practical fields for private initiative. In these three categories and in this order of importance lie the proper scientific activities of the Government.

The first scientific bureaus to be established had to concern themselves but little with the coordination of their programs. Each filled a definite need and its purpose was to gather facts in a designated field. Each one was organized because of clearly recognized national opportunities The several fields of science are now rather fully represented by bureaus This has led to duplication of effort because the boundary lines between fields of science have tended to grow indistinct We now talk much more about the borderlands of science Side by side with the growth in the number of bureaus and in the multiplicity of their functions, there should have been applied the principle of coordination of related work, no matter in what bureaus the work may be done.

Freedom of scientific work from political or policy-making influences is a second prime consideration. It is not our function to appraise national planning by federal agencies or express an opinion on it Whatever the trend of social or political thought and whatever the degree of national planning, the people of the country have the right to expect that the scientific services are always free to report and interpret the facts in a given field of enquiry as they find them and not as the government of the day may wish to have them reported or interpreted

Over and above the work of particular scientific bureaus, there is increasing activity on the part of the Government in undertaking large projects whose feasibility or justification are matters for technical decision from many points of view. scientific, economic, humanitarian. Examples of such projects are: irrigation, power development, flood control, soil erosion control, shelter belt, waterways, retirement of sub-marginal land and colonization Where huge sums are involved and large groups of people affected, it is more than ever necessary that decisions and policies should be settled only after the most thorough, competent and disinterested study of such questions as Is the project technically feasible? Will it accomplish its purpose? What are the alternatives, and has the best plan been selected? Will the benefits justify the expenditure? For technical advice on such questions, Congress and the Executive Departments should have ready access to, and should use, the best talent available both within and outside of the government services.

In an economic and social structure of growing complexity which we witness everywhere to-day, government, either federal or local, must of necessity assume a more positive rôle than was required in a simpler civilization. The extent of these new responsibilities is one of the most important questions of our times, but it is reasonable to assume that the guiding hand of government will not be relaxed in the future. With government in the stage of transition from the more passive and regulatory part played in the past, to one of more intelligent and broad supervision and initiation, it is the concern of every citizen that there be available to government the most competent and impartial advice which can be found. The endurance of our traditional form of government will depend in increasing measure upon the quality of expert judgment, tempered with experience, which is available to government, and the willingness of government to follow such judgment

The people of the country thus have a vital interest in the essential scientific services of the Government. It is to the people that the Congress and the Administration are responsible for the effective and efficient operation of these services It is, therefore, both proper and essential that the scientific personnel of the country, outside the government bureaus, should take an active and cooperative interest in seeing that the scientific work of the Government is conducted in such manner as to render the necessary services effective from the standpoint of science and efficient from the standpoint of management. In science, as in other fields, "to omit from the councils of men any sources of wisdom, judgment, or experience, or to ignore the normal aspirations of any group in the determination of public policy, is to rob society of some of the quality it might possess"

The scientific work of the government can not be maintained on a plane of high efficiency, and have the scope that the national welfare demands, unless the best civilian as well as official judgment is applied to the problems of the several bureaus and their personnel Congress has both the right and the duty to determine the worth of the scientific bureaus and make appropriations for their support. But in arriving at such a determination the individual members of Congress and the appropriate Congressional committees need to call upon disinterested civilian judgments outside the bureaus and not rely wholly upon the advice and information presented by the

bureau officials concerned. When the latter are efficient and broadminded, as most of them are, little more than confirmation of judgment and opportunity for helpful discussion may be contributed from outside sources But neither the existing methods of selection and appointment of bureau chiefs, nor the coordination of their work, has reached the point of desired efficiency It is a commonplace that projects are not always dropped when completed; that coordination is not always welcomed; that personnel is not always as alert and competent as it should be, that duplication of effort amounts in some instances to a disease, that the effective relation of governmental to non-governmental agencies is not a lively concern of some scientific bureaus, that the best advice is not always sought in the public interest; and that the better judgment of bureau chiefs can not always stand up, unaided, against political pressure for certain programs and expenditures.

Still more important, in the long run, is guardianship by scientific men outside the government lest the scientific bureaus be used for political ends. As fact-finding agencies the scientific services should be free to produce results that are not discolored by the opinions and snap judgments of policy-making political groups who may wish to put the dignity of "science" behind their plans in order to win public approval.

Granting, therefore, the need and opportunity for a science advisory service, there is required a form of organization that can function effectively and a personnel that is informed, alert, judicial, courageous and wise. In the last analysis "by their fruits ye shall know them", in other words, the strength and value of any science advisory body will grow or die in accordance with its ability to render valuable service, whatever may be its authority, composition or procedure. Recent events have given scientists an unprecedented opportunity to participate in the solution of important problems of policy, administration and personnel, by advising responsible officers of the government On the degree of their ability cooperatively to handle this opportunity will largely depend its continuance and extension.

All through history from the time that Archimedes was called on to aid, by his scientific inventions, in the defense of Syracuse, scientific men have been called to work for their governments and to advise them on matters within their fields of expert knowledge. Experience has indicated that there is no group more eager to place their knowledge and services at the disposal of the government, even at considerable personal sacrifice. Experience has also shown that these advisory services to government may be of great value if properly organized and treated with understanding and respect by those in political power

An outstanding example of successful scientific advisory service to government is found in the present organization of advisory councils to the British Government The first of these councils to be organized, and the one having the most extensive responsibilities, is the Advisory Council to the Department of Scientific and Industrial Research. The ten members of this council are chosen for their scientific and industrial qualifications and are appointed for terms of five years by the lord president of the Privy Council after consultation with the president of the Royal Society. The annual parliamentary grant for governmental scientific and industrial research is expended in a manner recommended by this advisory council, and the Department of Scientific and Industrial Research is in fact the administrative agency for carrying out the recommendations of the advisory council when approved by the lord president The members of this council attend meetings on official business on about twenty days in each year and receive an honorarium of 150 pounds

per annum in lieu of reimbursement for personal expenses. In addition to the responsibility for governmental research agencies, this advisory council also submits recommendations for governmental grants to universities for research projects and research fellowships and also to industrial associations on a joint contributory basis for scientific research of general benefit to these industries.

There is an analogous Medical Research Council and an Agricultural Research Council, both organized under the Privy Council and with similar responsibilities in their special fields. The finest scientific and industrial talent of the country is freely drawn upon by the government in the appointments of these advisory groups. It takes only a superficial study of the operations of these councils and their numerous subcommittees to become quickly convinced of the effective manner in which this sister English-speaking nation has created a plan of cooperation between the technical talent of the country and the government, which is leading to splendid results for the economic and social welfare of the country.

There are similar tendencies in the other European nations. In Norway, for example, no appropriations are made to certain scientific services of the government without examination and approval by a distinguished civilian advisory committee, and the government now has under way a study of means of improving and extending this advisory service. In Italy the National Research Council is assisting the government to bring about more comprehensive programs of research by Italian industrial organizations. In Russia the Academy of Sciences of Moscow has been called upon to aid the government in organizing the great system of research institutes recently created throughout the country and now in process of doing some of the finest and most progressive scientific work to be found anywhere in the world.

In the United States three notable steps have been taken by the Federal Government to provide for itself disinterested and competent advice upon scientific matters:

(1) The National Academy of Sciences was established by an act of Congress and approved by President Lincoln on March 3, 1863, with the specification that "the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment and report upon any subject of science or art, the actual expense of such investigations, examinations, experiments and reports to be paid from appropriations which may be made for the purpose," subject to the condition that "the Academy shall receive no compensation whatever for any service to the Government of the United States." Throughout its history the academy has rendered valuable service, principally in advising the government in regard to the organization of some of the federal scientific bureaus. In comparison, however, with the magnitude of scientific activity in the government and continued importance of problems involving organization, programs, personnel and budgets, I think that it may fairly be said that this arrangement has fallen far short of meeting the needs and opportunities for scientific advisory service. For example, the academy has been called upon by governmental agencies only about 100 times in the last seventy-two years, and of the eleven subjects thus referred to the academy directly by the Congress, only three related directly to the program or administration of the federal scientific services. These involved the National Board of Health (1870), the Coast and Geodetic Survey (1884), and a general report on the scientific work of the scientific services (1909). The other requests concerned scientific ques-

tions such as the introduction of the metric system, vivisection, the adoption of centigrade and Fahrenheit temperature scales and other matters of like nature.

The reason for this relative inactivity of the academy in the field in which it was created to perform can not, in my judgment, be ascribed to dearth, in the academy membership, of men eminently qualified to advise the government on its scientific problems, for there is no question but that its membership has contained men of outstanding distinction and accomplishments in all fields of science. There may be a minor element of weakness in the very fact that absence of active duty in advising the government has resulted in relatively little attention by the academy to peculiar qualifications for such service in considering nominees for election.

I believe that the major weakness in the present organization of the National Academy of Sciences, as an agency for advising the government upon scientific matters, lies in the phrase "whenever called upon by any department of the Government." There is no provision in the government, as there is in the British Government, whereby the scientific advisory services are automatically called upon when important scientific problems arise. The result is that few of the high administrative officers in the government, as they change from one administration to another, realize or take advantage of the opportunities for disinterested and competent assistance from the academy in handling the problems continually arising in the administration of the scientific bureaus under their jurisdiction. As a consequence this type of service has not been actively in the minds of the members of the academy, of whom the majority have rarely, if ever, been called upon to exercise this advisory function.

While, therefore, the National Academy of Sciences has had a distinguished history and has performed some very useful functions for the advancement of science, it has not handled the needs and opportunities for scientific advice to the government in an adequate manner. This failure is no reflection on the academy but has been, I believe, inherent in its organization and is also due in part to the type of public servant who is usually elected to high office in our government. For the most part these men have a legal training and a political and opportunistic outlook. They may be able and well-intentioned, but they, too, rarely have a sufficient scientific background or philosophic outlook to give them a sympathy and understanding of the nature, purposes and values of scientific work.

(2) The National Research Council was organized by the National Academy of Sciences in 1916 at the request of President Wilson as a measure of national preparedness in the face of the serious international situation at that time. At the President's further request, it was perpetuated by the National Academy of Sciences on April 29, 1919. As stated in its articles of organization, the purpose of the National Research Council is "to promote research in the mathematical, physical, and biological sciences and in the application of these sciences to engineering, agriculture, medicine, and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare, as expressed in the Executive Order of May 11, 1918." This executive order stated the objectives of the National Research Council to be "to stimulate research . . ., to survey the larger possibilities of science, to formulate comprehensive projects of research, and to develop effective means of utilizing the scientific and technical resources of the country for dealing with these projects, to promote cooperation in research at home and abroad . . ., to serve as a means of bringing American and foreign investigators into active co-

operation with the scientific and technical services of the War and Navy Departments and with those of the civil branches of the Government, to direct the attention of scientific and technical investigators to the present importance of military and industrial problems in connection with the war . . . , and to gather and collate scientific and technical information."

The National Research Council is, in a sense, an operating arm of the National Academy of Sciences and is permanently organized into divisions with representatives from all major scientific bodies. These divisions are served by numerous permanent and temporary committees, whose membership in each subject represents a cross-section of American leadership in the respective fields within and without government circles. There is thus provided an extensive framework for mobilizing the scientific forces of the country, which functioned with great effectiveness during the war and which is permanently available, even if not always active, as an important element of national preparedness.

The National Research Council is admirably set up to assist the government in one aspect of science advisory service; namely, in the organization and supervision of cooperative investigations aimed at specific scientific or technical objectives of interest to the scientific bureaus. For such purposes, the National Research Council is continually active, though, like other organizations, this activity is limited through limitation of funds for operating expenses. In its present organization, however, the National Research Council is not well organized for rendering effective advisory service to the government in matters of policy or organization. Its essentially representative character is admirable from the point of view of coordinating scientific agencies, but is not well adapted to the selection of the best personnel for advisory service on matters of policy. Furthermore, an inherent element of strength of the National Research Council is the inclusion of representatives of the governmental scientific services, but for obvious reasons, any organization which is created to give disinterested advice to the government on matters of policies, programs and administration of its scientific bureaus, can not contain in its membership representatives of these bureaus. For these reasons, therefore, the National Research Council is not well adapted to act as scientific adviser to the government.

(3) The Science Advisory Board was appointed by Executive Order of President Roosevelt on July 31, 1933, "in order to carry out to the fullest extent the intent of the above Executive Order (that of President Wilson creating the National Research Council)—with authority, acting through the machinery and under the jurisdiction of the National Academy of Sciences and the National Research Council, to appoint committees to deal with specific problems in the various departments." This board was created for a limited period, which expired on December 1, 1935, and was composed of the following scientists and engineers:

Karl T. Compton, *chairman*, president of the Massachusetts Institute of Technology, Cambridge, Massachusetts.

Roger Adams, professor of organic chemistry and chairman of the department of chemistry, University of Illinois, Urbana, Illinois (president-elect of the American Chemical Society).

Isaiah Bowman, chairman, National Research Council; Director, American Geographical Society, New York City (now president of the Johns Hopkins University).

W. W. Campbell, president, National Academy of Sciences, Washington, D. C.

Gano Dunn, president, J. G. White Engineering Corporation, New York City.

Simon Flexner, formerly director of the laboratories of the Rockefeller Institute for Medical Research, New York City.

Frank B. Jewett, vice-president, American Telephone and Telegraph Company; president, Bell Telephone Laboratories, Incorporated, New York City.

Lewis R. Jones, professor of plant pathology, University of Wisconsin, Madison, Wisconsin.
Charles F. Kettering, vice-president, General Motors Corporation; president, General Motors Research Corporation, Detroit, Michigan.
C. K. Leith, professor of geology, University of Wisconsin, Madison, Wisconsin.
Frank R. Lillie, Andrew MacLeish distinguished service professor of zoology and embryology and dean of the biological sciences, University of Chicago, Illinois.
John C. Merriam, president, Carnegie Institution of Washington, Washington, D. C.
R. A. Millikan, director, Norman Bridge Laboratory of Physics, and chairman of the executive council, California Institute of Technology, Pasadena, California.
Milton J. Rosenau, Charles Wilder professor of preventive medicine and hygiene, Harvard Medical School, and professor of epidemiology, Harvard School of Public Health, Boston, Massachusetts.
Thomas Parran, state commissioner of health of New York, Albany, N. Y.

The most active work of this board has been done through its nineteen special committees with an aggregate personnel of 101 scientists, engineers and industrialists, who, in each case, were selected for their peculiar fitness for the problem in question. It is significant proof of the willingness of the highest type of technical talent of the country to serve the government on important matters that not a single individual who was asked to serve on one of these committees refused the assignment. In some cases this work involved several months of almost continuous duty and in all cases was done without remuneration except for reimbursement of personal expenses incurred. These committees were usually under the chairmanship of a member of the board and were given the greatest freedom of initiative, and absence of red tape, actively to pursue their objectives. The effectiveness of their work is due jointly to their able personnel and to the freedom and responsibility which was given them.

The board as a whole met at intervals of two or three months to plan the organization of new projects, to receive and discuss the reports of its committees and to take action on matters of policy. While the committees were given great freedom in carrying out their studies and formulating their recommendations, the board itself exercised control of the manner in which these recommendations were submitted to the appropriate government officials and carried on the subsequent work of conference with these officials for the purpose of putting the recommendations, as far as possible, into effect.

The scope of activities of the Science Advisory Board is best illustrated by the names of the committees. These committees were set up to handle specific assignments, but most of them handled a succession of problems submitted to the board from the responsible government officers, who included department secretaries, the director of the budget, the federal coordinator of transportation and the President himself.

Executive Committee.
Committee on the Weather Bureau
Committee on the Geological Survey and Bureau of Mines
Committee on Economic Resources of the Boulder Dam Region
Committee on the War and Navy Departments
Committee on the Policy of the Government in relation to scientific research
Committee on Land Use
Committee on the relation between fundamental sciences and the scientific study of human problems
Committee on Railway Research
Committee on the Bureau of Standards
Committee on Surveying and Mapping Services of the Federal Government
Committee on Research in the Land-Grant Colleges
Committee on the Bureau of Chemistry and Soils
Committee on Soil Surveying and Soil Research
Committee on Medicine and Public Health
New Industries Patent Committee
Committee on the Design and Construction of Airships
Committee on Signalling for Safety at Sea
Committee on Biological Abstracts

In addition to the work suggested by these committees, there were some activities of a confidential nature, not publicly reported, and there were others which were carried through by the board as a

whole, notably the recommendation to the President of "A National Program for Putting Science to Work for the National Welfare."

Although the executive order of the President assigned to the Science Advisory Board a task which proved to be of considerable magnitude, no provision was made for financing the operations of the board. The necessary expenses of operation included secretarial help and office supplies, reimbursement of travel and other out-of-pocket expenses of the board and its committees, and occasionally the employment of an expert to gather and collate necessary information. The appointment of the board would therefore have been largely futile had not the Public Administration Clearing House made an initial grant to support the work of the board in its first month or two, and had not the Rockefeller Foundation then stepped into the breach and made an appropriation to the board of $50,000, which was just sufficient to cover its operating expenses for the balance of its term of appointment.

It would be impossible in this brief article to go into the details of the activities of the Science Advisory Board. A full description of these activities may be found in the two official reports of the Science Advisory Board, published in September, 1934, and November, 1935. A limited number of copies of these reports is available on application to the National Research Council, 2101 Constitution Avenue, Washington, D. C. It may be interesting, however, to summarize very briefly the extent to which the work of the board has led to positive results.

In several instances the board was requested by department secretaries to nominate candidates for appointment to the highest administrative posts in scientific bureaus. In every case the appointments were made in accordance with the nominations submitted by the board.

In a goodly number of cases the recommendations by the board have been put completely into effect. These cases include the consolidation and strengthening of the Mineral Statistics Services, the institution of scientific methods for determining the efficacy of measures to combat soil erosion, increased appropriations for scientific research in the public health service, the appointment by the President of a planning committee on mineral policy, the introduction of new features of program and interdepartmental coordination in the work of the United State Weather Bureau, and the introduction of a cost accounting system with a new form of organization for appropriation purposes in the activities of the National Bureau of Standards.

In the majority of cases the recommendations of the board have been partially put into effect as fast as appropriations, personnel or ability to secure necessary authorization or cooperation have permitted. In this category satisfactory progress is being made in the organization of a cooperative research agency by the Association of American Railroads, in the application of new methods of forecasting by the Weather Bureau, in a realignment of some aspects in the programs of the Geological Survey, Bureau of Mines and Bureau of Standards, and in the modification of practices in the Patent Office and in the handling of patent cases in the courts.

In some cases the board's report was purely factual, as in the study of the economic resources of the Boulder Dam region and in the compilation of information and programs for the use of federal agencies engaged in studies of soil erosion and land use.

In the report on mapping services of the Federal Government, there was recommended a consolidation of those bureaus whose sole activity is the production of maps to form a single efficient mapping bureau. It was shown that

decided economies could thereby be secured and that the enormous economic interest of the country in the completion of its mapping program could be greatly facilitated. Unfortunately, lack of authorization to effect these consolidations has blocked the favorable action which for a time appeared probable, and it is greatly to be hoped that this subject will receive due consideration in the next session of Congress.

On the whole the board feels that the positive results of its work have been as great as could reasonably have been expected and it offers tribute to the sincere desire of government officials to conduct the affairs of the scientific bureaus for which they are responsible in such manner as to give the best possible service to the country. The friendly cooperation of department secretaries and bureau officials throughout has been most noteworthy.

Conclusion

Whatever may have been the successes and failures in the efforts of the National Academy of Sciences, the National Research Council and the Science Advisory Board to render effective advisory service to the Federal Government, there is no doubt that the most important consideration is of the future rather than the past. The ideal program would be the planning of a science advisory service based upon the lessons from all past experience. Realizing this fact, the President has opened the way for such a constructive step through the following letter addressed to the president of the National Academy of Sciences.

THE WHITE HOUSE

Washington

July 15, 1935

Dr. Frank R. Lillie,
President, National Academy of Sciences,
Constitution Avenue and 21st Street, N.W.,
Washington, D. C.

My dear President Lillie:

In accordance with recommendations from you and from Doctor Karl T. Compton of the Science Advisory Board, I am signing an Executive Order extending the Science Advisory Board to December 1, 1935, in order that the work now under way can be carried on until more permanent arrangements are made by the National Academy of Sciences.

The National Academy of Sciences under the provisions of its Congressional charter is required "whenever called upon by any department of the Government to investigate, examine, experiment and report upon any subject of science or art." It has, through its National Research Council, permanently organized contacts with the scientific and technical bodies of the country. During the past two years it has been implemented by the Science Advisory Board, through which its members have become more intensively acquainted with the scientific services of the Government and their problems.

In order to secure the most effective scientific advisory service, based on the experience of these three agencies, I hereby request the Academy to provide some single agency, board or committee which can carry on the work of the Science Advisory Board and related activities after December 1, 1935.

Upon receipt of word from the Academy as to the committee or other organization through which the Academy wishes to perform this service, I shall be glad to request the Government departments and scientific bureaus to utilize and cooperate with that agency.

Sincerely yours,

S/ Franklin D. Roosevelt.

Just what form this revised science advisory service will take as to its organization and methods is now in process of development. Certain aspects of the situation must receive consideration. It is important that duplication of science advisory services be eliminated as far as possible and that the existing ones be closely coordinated.

For this reason a science advisory service should certainly be set up under the Congressional authority vested in the National Academy of Sciences but in such manner as to avoid any conditions which may hitherto have prevented the academy from its best possible performance in this field. It is also important that the science advisory service operate in sympathetic coordination with the National Resources Committee, which has been given broad powers to coordinate and mobilize the resources of the country, both physical and intellectual.

The Science Advisory Board, in March, 1935, submitted to the President a recommendation embodying its best judgment at that time in regard to the organization of a permanent science advisory service. Certain situations which have subsequently intervened make it probable that some details of this recommendation will have to be modified, but the basic features of the plan there outlined would seem to embody the best past experience of the United States and Great Britain as applicable to the situation under our own government.

This plan envisages the appointment of a central science advisory board or committee of completely non-political character, selected by the National Academy of Sciences. Such a board would have certain authority under the Congressional charter of the academy. In addition to this, it is believed to be essential that the board should have specific recognition and authorization by the President of the United States and his administration in order that it may readily be recognized and used by his official family of the department secretaries, since experience has shown that it is through these secretaries that requests for advice in scientific programs or policies are most frequently received. It is furthermore specifically recommended that the director of the budget be requested by the President to secure the advice of this board in regard to the budgets and appropriations of the scientific bureaus. While doubt has been expressed in some quarters as to whether such an arrangement would be entirely acceptable to all parties concerned, this plan has operated effectively in Great Britain and has precedent in our own country in the work of the Fine Arts Commission. It has furthermore been warmly approved by a number of prominent men who hold, or have held, official positions in the government departments which are involved.

In order to enable such a central science advisory board to deal effectively with problems of the various departments, it is further recommended that permanent subcommittees of the central board be established in connection with the more important scientific bureaus of the government. Ever since the establishment of the National Bureau of Standards, there has been a visiting committee of this type, which has operated with considerable influence in consultations with the Secretary of Commerce, the director of the bureau and the director of the budget. More recently at the recommendation of the Science Advisory Board, a similar advisory subcommittee has been set up to serve the United States Weather Bureau. There are advisory committees also attached to the United States Public Health Service and the Geological Survey. The present proposal would coordinate these advisory groups through the central science advisory board and would bring to the aid of the Federal Government the best scientific and technical talent of the country in a coordinated advisory service on scientific matters. Such a comprehensive service would be of inestimable value to the future welfare of the country and it is greatly to be hoped that some form of organization along these general lines may be consummated and may receive from the government the necessary authorization and financial support for its effective functioning.

ON THE STRUCTURE OF SOLID BODIES

By Dr. EUGEN WIGNER

PROFESSOR OF MATHEMATICAL PHYSICS AT PRINCETON UNIVERSITY, 1930–35

BUDAPEST, HUNGARY

(1) PHYSICS always develops in two directions. One front pushes forward towards phenomena which do not yet fit into the general picture, and the victories on this front are marked by important changes in our fundamental concepts. On this front to-day the main struggle is for a better understanding of nuclear phenomena by the application of both theory and experimentation. But, apart from this search for new concepts, there is a constant effort directed toward the deepening and broadening of our knowledge of phenomena which, we believe, *can* be understood on the basis of existing concepts and theories. Doubtless this second front is of less importance. It rarely leads to fundamental discoveries in physics proper but supports rather the studies on the borderline of this science, such as physical chemistry and the applied sciences. Spectroscopy suddenly changed, about six years ago, from the first to the second category, and not much later it became apparent that the study of the solid body belongs also to this second class. In spite of this, it remains one of the most attractive of all fields, since it deals in a scientific way with those subjects with which we must deal in our everyday experience. For example, we are never afraid when dropping a key that it will fly to pieces, as glass would, nor do we fear that a gold coin will dissolve in water nor evaporate if left for awhile in the open air.

X-ray studies have revealed that most of the solid bodies in our surroundings are crystalline. This does not necessarily mean that they are formed by one single crystal—although even this is true for bodies of such enormous size as icebergs. More commonly, they are polycrystalline, like the metal parts of ordinary tools, *i.e.*, a conglomerate of microscopic crystals of various sizes. Crystalline in this connection does not mean a regularly shaped body of the kind we see in our crystallographic collections, but only that the grains have a regular *inner structure* arising from the arrangement of the atoms in surprisingly regular *lattices*. Samples of such lattices are shown in Fig. 1. (The circles represent the centers of atoms; the lines have no physical significance and are drawn only in order to facilitate space-vision.) The region over which the regular arrangement has a certain orientation is called a microcrystal and may have a size anywhere from .00001 mm to 1 mm or even more. These microcrystals, generally possessing irregular boundaries, are heaped together in an apparently random manner to form the polycrystalline body. (Very little is known about how the microcrystals with their different orientations fit and stick together. Some assume a separate very thin noncrystalline phase which "pastes" them together, but there is no definitive evidence for this.)

The crystalline and polycrystalline substances constitute by far the greater part of all solid bodies found in nature. Practically all rocks are conglomerates of crystals, ice is crystalline, and so are all metals. The grains of sand are minute crystals and loam also is crystalline. Apart from the glasses and substances of organic origin, like wood, there are very few non-crystalline solids.

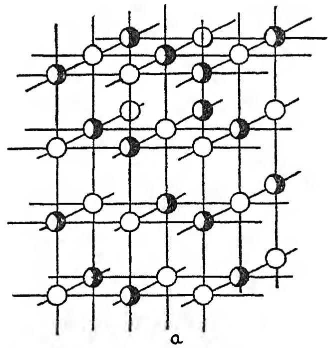
(2) A distinction not necessary in the case of gases or liquids must be made between different kinds of properties of solids.

Evidently, the consideration of a regular lattice is much simpler than that of an irregularly spaced heap of atoms. It is important, therefore, that many of the properties of a polycrystal are the same as those possessed by a perfect single crystal. These properties are connected with phenomena which affect the bulk of the material, like vaporization, fusion, specific gravity and compressibility. Our understanding of these "insensitive properties" is naturally the farthest advanced, and we shall devote most of our attention to them.

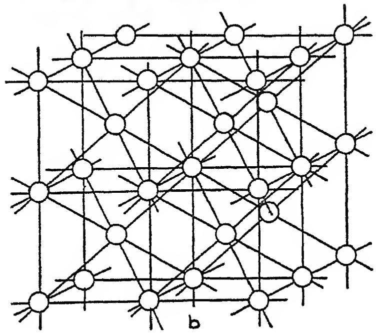
Unfortunately, a great many very important properties belong in a second "sensitive" class. The breaking strength, for instance, is determined by the very weakest part of the crystal; one single imperfection of certain types may suffice to cause rupture under a very low stress, a tenth or even a hundredth of that which a perfect crystal could support. Fig. 2 gives a rough picture of how this can happen: the stress, characterized by the stress lines, concentrates in the neighborhood of the imperfection and attains values which are many times those in the bulk of the material. This highly concentrated stress can widen the notch and finally break the whole body. Thus, the parts of a solid which lie above and below a crack not only do not increase the strength of the material but very definitely weaken it. One can say that the strength of a solid is much smaller than that of its weakest part.

The situation for the electric breakdown of insulators parallels that for the elastic limit (the smallest stress which causes a permanent deformation), and the study of these sensitive properties of crystals involves besides a knowledge of the crystal in bulk, its criminology, *i.e.*, a knowledge of the most usual faults and imperfections.

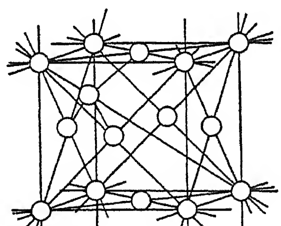
In addition to these extremes, there are, of course, a number of borderline properties. These are partly connected



a



b



c

Fig. 1a. Part of a KCl lattice. The shadowed spheres denote the positions of the K ions, the empty ones the positions of the Cl ions. The distance between nearest neighbors is .00000031 mm. Ordinary rocksalt has the same lattice with somewhat smaller dimensions.

Fig. 1b. Part of the lattice of an alkali metal. The spheres represent the centers of mass of the atoms. The distance between nearest neighbors is .000000372 mm in sodium.

Fig. 1c. Unit cell of the diamond lattice. The distance between next neighbors is .000000154 mm. Si has a similar lattice with a distance of .000000234 mm between nearest neighbors.

with the external surface, as, for example, the thermionic emission of electrons, or with the internal boundaries of crystallites, exemplified by the electric conductivity of compressed salts. All these properties are influenced to some extent by small contaminations. With extreme care and sufficient experimental skill reproducible results are sometimes obtainable for these phenomena, and they are then frequently as amenable to theoretical interpretation as the insensitive properties.

(3) Let us return now to the insensitive properties. Even with regard to these, the variety found in solids is much greater than that in gases. From the empirical point of view, four main classes, with many transitions between them, can be distinguished. This classification, which in its essentials goes back to Grimm, contains:

(*a*) *Molecular lattices.* Inert gases or saturated compounds like He, Ne, A,

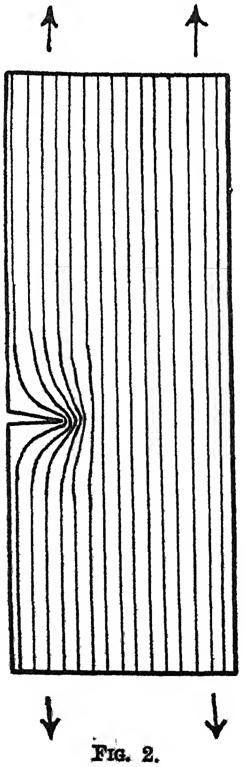


FIG. 2.

etc., H_2, N_2, O_2, etc., CH_4, C_2H_6, H_2O, H_2S, etc., and all organic compounds form such crystals. They all have low heats of vaporization and condense only at comparatively low temperatures. They are soft and moderately brittle, are good insulators and are transparent, except in spectral regions in which the building molecules themselves show absorption.

(*b*) Metals have in many respects properties opposite to those of class *a*. The binding forces between the atoms are much higher and the heat of vaporization greater, and they have an increased hardness. Their most remarkable property is, of course, that they are good conductors for electricity and heat. They are opaque and owe many of their important applications in industry to their plasticity; that is to say, they break only after great deformations.[1] Their solubility in each other is considerable (alloys), but they never dissolve in solids of other classes.

(*c*) *Valence lattices* (diamond, quartz, carborundum) and

(*d*) *Ionic lattices* (salts) are rather similar types. They both have high heats of vaporization, strong cohesive forces, are transparent like molecular lattices, are good insulators and are hard and brittle. The main difference between them is that while the former are formed from neutral atoms, the building stones of the salts are electrically charged ions, held together by the electrical attraction between opposite charges. They dissolve, therefore, in liquids with high dielectric constants like water, which diminish the electrical attraction of the ions down to a small fraction of its original value.

[1] This is why they do not break if dropped. The sudden stopping on the ground causes great stresses. In consequence of this, the metal will suffer a plastic deformation which will not cause rupture, however. In consequence of the plastic deformation the metal will act as its own shock absorber by allowing more time for the stopping of the bulk of the material.

This characterization of the four groups of solids should be understood in the same sense as should a similar characterization of a class of plants in botany. It does not give ironclad rules, but rather ideals from which the real cases often deviate; especially is this true for the more complicated compounds. Also various kinds of transitions occur between the four groups. Sometimes inside individual layers we have a lattice of one kind, while the forces *between* the layers are characteristic of another of our classes. There are also cases which are really transitional in all their behavior between two (or even three) groups, especially between valence and ionic lattices.

These exceptions are rare, however. The importance of the four groups becomes most evident, perhaps, if we realize that instinctively we classify into one of these groups all solid bodies of inorganic origin, which happen to fall into our hands. The above characterization of the four groups is the scientific description of what all of us would expect with regard to vaporization, hardness, electric conductivity and brittleness after some inspection and handling of such substances as condensed CO_2, rhodium, carborundum and Glauber's salts, even if we had never seen them before. On the other hand, we wouldn't quite know what to expect from transition lattices such as carbide or even graphite.

(4) The enormous differences between the physical properties of different kinds of lattices make it evident that the forces holding the atoms or molecules together are very different in the four cases. In order to understand the origin and nature of these forces, we must first recall the structure of isolated atoms and molecules. This is probably well known to the readers of the SCIENTIFIC MONTHLY. It is only recently that Professor Eyring gave an excellent review of this subject in these pages.[2] According to Rutherford, the atom contains, first of all, a heavy nucleus, containing all the positive charge and (except for about one part in two thousand) all the mass of the atom. The center of gravity of the atom practically coincides with the nucleus, so that in Fig. 1 the circles may be regarded alternatively as the positions of atoms or nuclei. This nucleus, though small, is full of mysteries, which fortunately are of no importance in understanding the solid state. The negative charges, which exactly compensate the positive charge of the nucleus of a neutral atom, are carried by light particles, the electrons. These electrons surround the nucleus like an enormous cloud with dimensions a hundred thousand times that of the nucleus, although the cloud is itself only about .0000001 mm thick. Quantum mechanics, created by Heisenberg, Schrodinger and Dirac, unravelled for us about eight years ago the exact laws of motion of this electron cloud. It is now possible to calculate the density of this cloud at different distances from the nucleus, and from this one would naturally expect to obtain important information concerning the structure of solids, by comparing the density distribution of the electrons for different distances in the lattice. The outermost or valence electrons are responsible for the entire chemical behavior of the atoms. In Fig. 3, the full line represents the density of the valence electrons as a function of the distance from the nucleus. In addition to this, the position of the nearest neighbor is marked on the abscissa and the density distribution of the valence electron of this neighbor is plotted *in the direction of the first atom* as the dotted line. The first plot is for He, the most characteristic representative of a molecular lattice; the second is for sodium, a typical metal; the third for

[2] SCIENTIFIC MONTHLY, 39: 415–419, November, 1934.

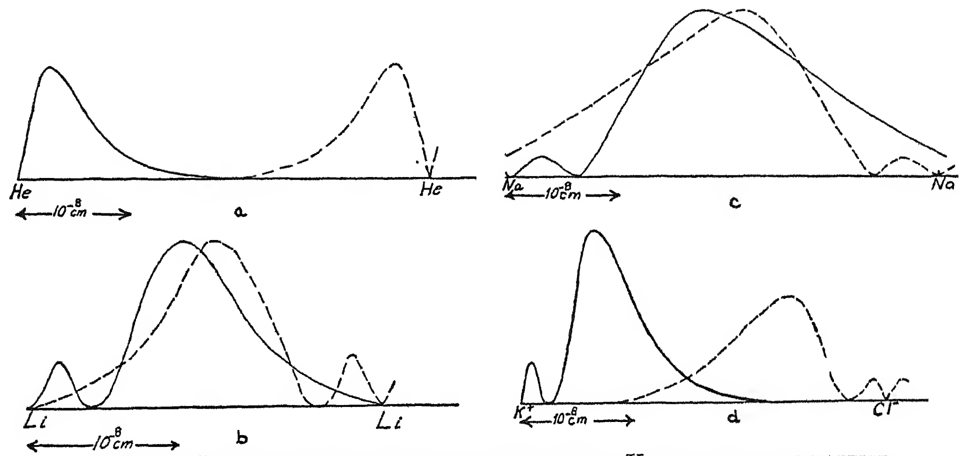


FIG. 3a. CHARGE DISTRIBUTION OF TWO NEIGHBORING He ATOMS IN THE LATTICE.

FIG. 3b. CHARGE DISTRIBUTION OF EXTERNAL ELECTRONS IN FREE Si ATOM (FULL LINE). THE DOTTED LINE IS THE CHARGE DISTRIBUTION OF THE VALENCE ELECTRONS OF ANOTHER Si ATOM, PLACED AT THE SAME DISTANCE FROM THE FIRST AS IN THE LATTICE.

FIG. 3c. CHARGE DISTRIBUTION OF THE VALENCE ELECTRON IN FREE SODIUM ATOM (FULL LINE). THE DOTTED LINE IS THE CHARGE DISTRIBUTION OF THE VALENCE ELECTRON OF ANOTHER SODIUM ATOM, PLACED AT THE SAME DISTANCE FROM THE FIRST AS THE NEAREST NEIGHBOR IN THE LATTICE.

FIG. 3d. CHARGE DISTRIBUTION OF EXTERNAL ELECTRONS IN K ION (FULL LINE) AND Cl ION (DOTTED LINE). THE DISTANCE OF THE ZEROS OF THE TWO PLOTS IS EQUAL TO THE DISTANCE OF THE NEAREST IONS IN THE KCl LATTICE.

the valence lattice of silicon and the last one is for KCl, which closely resembles ordinary rocksalt.

We realize at once an important difference between the molecular and ionic lattices (first and last pictures) on the one hand, and the metallic and valence lattices on the other. For the former, the overlapping of the electron clouds is small, in the latter ones it is so great that it is impossible to tell to which atom a certain valence electron belongs. In the former cases the constituent atoms or ions, although attracted by their neighbors, have their charge distribution but slightly affected. This is not so for the metals and valence lattices. There is no region between the atoms with a small charge density and consequently no forbidden region for the electrons. The electrons are able to pass from one atom to the next. Thus the valence electrons move freely and are common to the whole lattice. This is of decisive importance for the properties of these substances.

In molecular and ionic lattices, it is possible to consider the constituents as different entities. Born's classical theory of mechanical electric and thermal properties, which treats the atoms and ions of the lattice as individuals, attained its great successes for these lattices.

The great differences in the behavior

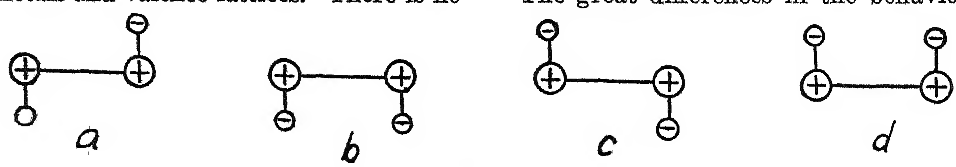


FIG. 4.

of the two classes are due to the different character of the constituents. These are neutral atoms in the first case, in the ionic lattices they are charged particles. The electric forces between ions are very strong, and this makes the cohesive forces, the heat of vaporization and hardness great. The distances between neighboring ions are given by the charge distribution, as illustrated in Fig. 3. The calculations of ionic radii were carried out by L. Pauling in California and show remarkable agreement with the values derived by Goldschmidt from observations. These lattices are always so constructed that the positive ions are surrounded by negative ions, the negative ions by positive ones. (*Cf.* the NaCl lattice in Fig. 1.) Since opposite charges attract each other, there are considerable forces holding these lattices together.

The nature of the forces in molecular lattices is not so simple. Van der Waals was the first to assume that condensation is caused by the same forces which are responsible for the deviation in the behavior of real gases from the ideal gas laws. This proved to be true in the case of molecular lattices, and the laws of these forces have been recognized by London and Wang on the basis of quantum mechanics and called van der Waals forces.

Of course, there is no attraction due to electric charges in molecular lattices, since the constituents are uncharged. And, indeed, the attraction can not be understood as long as we consider the electrons as charge clouds. But if we remember their corpuscular nature, we realize that they can form *dipoles* with the nucleus. The direction of this dipole will vary quickly because of the quick motion of the electrons. There will be no force, in the mean, on a dipole of constant orientation, since the attraction for one dipole orientation is as great as the repulsion for the opposite orientation—and all dipole directions are equally probable. But if two variable dipoles face each other, it will be possible that the two attractive configurations *a* and *c* of Fig. 4 will occur more often than the repulsive configurations *b* and *d,* although all the orientations for the *single* dipoles are equally probable. London and Wang have shown that this is actually the situation, and thus laid the foundation not only for a satisfactory theory of molecular lattices but also for a theory of the behavior of real gases.

Naturally, the van der Waals forces are much smaller than the Coulombic forces between ions. Thus, the cohesion in molecular lattices is small, the vaporization easily giving volatile substances. Also it is evident that these very small forces will be important only if no other stronger forces are present. Molecular lattices will be formed by saturated compounds and inert gases.

(5) Fig. 3 shows us that the metallic and valence lattices form the more compact modification of matter, as contrasted with molecular lattices and salts. This gives important information concerning the question of the behavior of solids under extremely high pressures: according to Bernal, who first emphasized this point, they will go over into metals or valence lattices. A convincing piece of evidence for this point of view, which is quite independent of calculations of charge distribution, is furnished by the phenomenon of *allotropy*. This is the name given the phenomenon of the appearance of the same chemical element in different "modifications" with widely different physical and chemical properties. The ordinary, yellow (white) form of phosphorus forms a somewhat complicated molecular lattice. It is a good insulator, soft, dissolves in organic solvents and has a density of 1.83. Bridgman at Harvard subjected this element to very high pressures, and the lattice "collapsed." It transformed into *black*

phosphorus, which has a density of 2.70, is a fairly good conductor of electricity and insoluble in organic liquids. And this is the general rule: Whenever an element has two allotropic modifications, the *metallic or valence form has the higher density.* The following table illustrates this point:

As, metallic	5.72	yellow .	2.03
diamond	3.51	graphite	2.24
black phosph.. .	2.70	yellow . ..	1.83
Se, metallic	4.82	red	4.47
Sn, white	7.28	grey . .	5.76

Calculations made in our laboratory by H. B. Huntington show that metallic hydrogen should also exist, though only under extremely high pressures, and that it should have a density many times higher than that of the usual molecular form.

I shall not go into detail with regard to the next question which naturally arises—the cause of the fundamental difference between valence and metallic lattices. Although both form in the compact modification of matter, apart from the high heat of vaporization and boiling point, they have nothing in common. The reason for this is deeply rooted in the principles of quantum mechanics and has been brought out but lately by works of Peierls and Brillouin. According to their investigations, it is essential for a valence lattice that the number of valence electrons be *even,* and this rule holds without exceptions. We owe much valuable information concerning the structure and crystal form of valence lattices to Pauling and Slater, but a review of their work would greatly exceed the scope of this report.

I hope that I have succeeded in imparting to the reader the impression that the foundations for the understanding of the nature of the solid state are laid. Still, it will require much thorough work, perseverance and many new ideas before we will be able to add the theory of solids as a finished story to the building of physics and before we will be able to apply with success our knowledge in industry.

The progress in the explanation of the properties of solid bodies is due on the theoretical side to the newly developed quantum mechanics, and experimentally mainly to the study of crystal structure by x-rays. Without these tools we would face these problems as helplessly as we still face the problem of liquids where x-ray studies have proved less efficient so far.

IN QUEST OF GORILLAS

III. KIVU, LAND OF OLYMPIAN CLOUDS

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

WE got down in front of the hotel at Bukavu, which was to be our home for the next ten days, and were presently greeted by the genial hosts, Mr. and Mrs. Stephenson. It was indeed a pleasure to meet these sterling English people and their three little children and to live in their hotel. Mr. Stephenson, an ex-soldier, had taken part in the siege of Gallipoli and other scenes of the Great War, while Mrs. Stephenson had served as a war nurse. He owned a coffee plantation near by, while she was the manager of the hotel.

That afternoon I walked down the main street of Costermanville, along the high promontory that runs out into the lake. Wave-like mountains run along parallel to the lake on both sides of it and others cross the view on the north. I did not then realize that I was looking only at the very narrow tip of one horn of the lake, the main body of which lies far to the north. Almost the whole town, consisting chiefly of this one broad avenue, had the appearance of being brand-new. Many smart-looking new brick houses with bright-colored roofs were going up, the brush-like *Casuarina* trees on either side of the road had been planted not very long ago and everything was spick and span from the foot of the long hill to the bright-colored government buildings near the tip of the long fish-hook-like curve. All newly cut embankments and roads were of the bright red color that is so characteristic of tropical Africa.

Here at about 4,500 feet above sea-level the air was dry and fairly cool, the bright sunshine was not too intense and one could lightly climb the hills and absorb the inspiring vistas of this land of titanic earth waves. This town, I was told, had grown from practically nothing in the past three or four years, partly as a result of the opening of the automobile road from Lake Tanganyika. About the town there was nothing of the roughness or recklessness that is so often seen in towns of rapid growth. All was proceeding according to an orderly and well-thought-out plan. It is one of the advantages of the excellent system of government in the Belgian Congo, in which, so far as the evidence presented itself to me, a consistent and highly successful attempt is being made to build up a beautiful country for the benefit of all parties concerned and with due regard for the rights of all.

Then I walked in the opposite direction, up the long hill to the empty market-place at the top. On each side of the street there is a line of small shops, mostly owned by the numerous great Belgian corporations, *Sociétés Anonymes* with alphabetic names, that have similar shops distributed all over the vast territory of the Belgian Congo. Here the shops offered a convenient place for the natives to spend the money they had gained by selling their produce in the market at the head of the street.

The market-place was empty, but many large black and white vulturine crows were soaring and flying over it. In the center was set up a hexagonal basaltic column about three feet high, which I knew must have come from some

place near by. This gave me a clue to the geologic structure of the surrounding mountains, which I was anxious to verify by further observation.

Toward evening I reached the top of a high hill overlooking the promontory on which the town was built. Evidently this spot had been fortified before or during the great war; before this Bukavu was nothing more than a native village, but now it commanded the main road from the south to Lake Kivu. Apparently no guns of any great size had been mounted here, but the low mounds and ditches would have been suitable for sharpshooters and machine guns. It was now solitary and a fine place from which to view the gray wave-like mountains and the splendors of the sunset. As I came down in the dusk toward the native village the rhythmic sounds of melodious voices humming for the dancers and the tinkling of many box-pianos (lukimbe) came up through the still evening air.

The next morning I went for a stroll through the native village, which lies at the neck of the promontory, and then some distance along the shore of the lake west of the promontory. Where all is new and strange almost everything is worthy of note, but I will begin with the activities of the street-cleaning gang in front of one of the shops of the numerous *Sociétés Anonymes*. Five men were seated basking in the plaza, posed like black Buddhas; they were about equally spaced from one another, like bees building a honeycomb. Each man held a short round broom, much like the kind that witches are supposed to carry; with this he slowly swept half-circles in front of him, pushing the leaves and scraps to the circumference. Every little while all five men would hitch forward very gently, so that the growing front line of leaves and rubbish was almost imperceptibly pushed out toward the gutter. I did not wait to see the end of this very slow moving-picture, but probably when one widening segment was cleaned off in this way, the men were under the painful necessity of getting up and walking across the plaza to begin a new cycle of well-moderated labors. Anyhow the result was an immaculately smooth and clean-looking plaza and the operation well illustrates a principle which the social Hymenoptera discovered millions of years ago: namely, the successful integration of almost infinitesimal efforts into purposive results that are often of great magnitude.

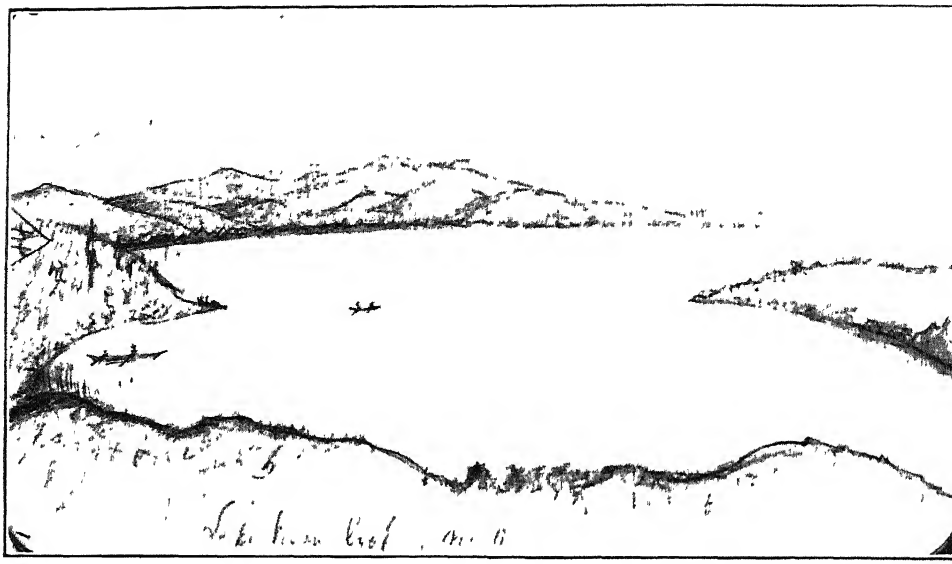
The incident also illustrates the African's gift for socializing labor, in the sense that labor becomes a social event, a training school in the fine arts of declamation and oratory. All this helps to disguise, at least in part, the fact that one lives under the curse of the descendants of Adam, who was condemned to earn his living by the sweat of his brow.

The visitor also gets the impression here and elsewhere that, as the arrangement works out, the blacks on the whole get far more benefit out of the foreigners than the reverse. For the foreigners keep the peace, and although the excitements and plunders of inter-tribal war are stopped, as well as the attractions of stealing women and making slaves, one is at least relieved of the constant strain and can bask peacefully in the sun; also the whites provide many jobs, especially on the roads; and one can move ever so deliberately with a moderate-sized basket of dirt on one's head and then get money to buy a swagger second-hand shirt or a real cast-off vest. Even the prisoners, who wear a brass collar around their necks and are thus tied together in long strings, do not look miserable or abused. They work on the roads not a bit harder than anybody else and jabber no less loudly and incessantly. One man with a gun is sufficient to guard a large number of prisoners, who seem quite resigned to their fate. Many a harassed man in America would find prison life in Africa a vacation.

The post-office near by offered another

—*Photograph by E. T Engle*

WHAT THE WELL-DRESSED WOMAN WEARS AT BUKAVU



—Sketch from Author's Note book

LAKE KIVU, LOOKING NORTH.

example of the African's pliant attitude toward life as it comes. There was a long line of natives with assorted old hats and other fragments of white man's clothing waiting to collect the mail for their masters. Although the line moved forward very slowly nobody betrayed the slightest trace of hurry or irritation, and that for several reasons In the first place, it was their job to do just that, at the master's orders and at his expense. Secondly, even if it had been their own time they were spending, what of it? Thirdly, several of the near-by messengers in red fezzes, who were basking in the plaza, were tinkling the native box-pianos. Of course nobody was really stirred by this droning, in which they were suffused all the days and nights of their lives; but it afforded an agreeable tonal background for their *andante* reveries.

I, being a foreigner and therefore afflicted with the peace-destroying urge to be up and doing, must be getting on with my walk. So I turn down a long incline that leads to the populous native village at the foot of the hill Some of the nabobs living in the houses along the terrace at the top of this hill do me the honor to interrupt the business of absorbing energy from the sun and to turn their eyes to inspect the "queer 'un." The frequent smiles which we exchanged indicated how amusing each looked to the other. But I always gazed with gravity and respect upon the thrice venerable old dames who were trudging up the hill with huge loads that they had carried for many miles.

So I go on down the long red hill to the bottom, where there is an enormous pit of red clay from which many blacks have taken out the material for bricks. Here is a gang of them in a great circular depression, mixing the clay with water by treading upon it in the manner of the biblical wine-treaders. I open up my camera and prepare to take a picture of the men in the pit. But I can not resist the temptation to show one or two of them who are near by the beautifully clear image in colors which is projected right side up on the ground glass at the bottom of the folding box. Oh, what ejaculations of surprise and approval:

"E-e-e-e-e-e-e!" (*diminuendo*) "Ah! Keh!" (*staccato*), in the wheedling, crooning tones of a mother to her infant. But all this was too much for the curiosity of the men in the pit. Out they scramble, bearing quantities of red clay on their feet, and I am nearly mobbed in their bovine attempts to push closer and look in the wonder-box. Many get a look and soon all yield good-naturedly to my energetic gestures and gesticulations

The next day (July 27) was market day (which occurs on every fifth day) and for the newcomer this is one of the great sights of Africa. From the villages that dot the nearly bare mountainsides a straggling army of blacks pours down the main path leading to "market hill." Women come trudging in with great basketsful of many kinds of produce on their backs; men, women, children and babies come to buy or sell and look on, and all together they send up a roar or hum that can be heard a long way off. But however interesting the people might be as individuals, there were too many of them crammed into one place, so after taking a casual look at the many groups crouching around their baskets, I went on up the path leading to the surrounding hills, going upstream against the procession of men with spears and women with burdens Many of them saluted or gave me a cheery "Jambo, Bwana" as I passed. A few of the men were tall and thin, with rather narrow noses and less coarse features. They were rather haughty in mien and seldom saluted They did not fail, however, to step aside to let the white man pass; nor did I care to interfere with the custom of the country, which unhesitatingly gives the priority to the white race on every occasion. This seems the only practicable rule, and I never noticed the slightest inclination to question its finality. These tall men very probably had in them the blood of northern invaders, the "cattle-keeping aristocracy" of East Africa. At the other extreme, some of the men had squat figures. In between

—*Photograph by H. C. Raven*

MARKET-DAY AT BUKAVU.

—Sketches from Author's Note-book

FALLS OF THE RUZIZI AT BUKAVU

GORGE OF THE RUZIZI, LOOKING SOUTHWEST

were the average run of medium-sized, flat-nosed blacks More women were dumpy than otherwise

Native clothing predominated among these up-country people and what little there was of it was worn with a dignity and grace that were in refreshing contrast to the ridiculous appearance of all those that by hook or crook could get hold of some cast-off garment of the whites Greatly protruding abdomens and tumor-like umbilici were very frequent among the little boys; cases of terrible sores on the legs, although fairly common, were by no means as numerous as they were in many other parts of Africa. The skin was usually very dark, the lighter skin as well as mixed breeds being much rarer than in the lower Congo and West Africa In general, really beautiful native articles seemed scarce and not very good. The native spears and knives were fair, but no decorated pottery, no beautiful baskets nor elaborately decorated gourds were noticed. One wonders how far this is due to replacement by articles of foreign manufacture.

As I walked along the mountain path I passed through several hamlets half hidden among the tall banana plants. Some of the older people were at home, basking in the sun in front of their round huts, while the boys played about or looked after the few long-horned cattle.

Making a wide detour around one of the hills I gained my first glimpse of this part of the Ruzizi River, where it breaks through the mountains south of the lake. Sitting down at a point high above the river and looking downward and outward, I tried to sketch in my notebook the wavering profiles of the hillsides as one behind the other they ran down toward the winding river. The first sketch was pretty crude, but by coming back to this neighborhood several times I came gradually to realize some of the underlying elements of the problem, so that finally, after various trials, I produced a pencil sketch that later brought to my family and friends at home some faint suggestion of the magic of that scene in distant Africa.

In such a country, with so much to see and record, the time passed quickly; nevertheless, we were all uneasy at the many delays that lay between us and our real objective, the gorilla forests Even after Raven and McGregor arrived a few days later, it proved exceedingly difficult to secure another camion to carry us and our equipment up into the mountains.

On other occasions I strolled along the shore of the lake, west of the promontory or peninsula, chiefly for the purpose of examining the rocks which were exposed there On the way I passed through the native village where the brickyards are. In front of one of the houses were several small children, one tiny one crying and a larger child jeering at it, just as white children do. From this and other examples I learned that the natives are very sensitive to ridicule or to the feeling of shame. This is one of the chief means by which the individual is forced to adopt the standards of the tribe, just as among whites But in general, while older children may jeer at the younger ones, they are amazingly good to the babies, and mothers frequently hand over their babies to be carried around by tiny boys, who soothe them and look after their needs with the greatest faithfulness.

Going beyond the fine Belgian hospital for the natives, I walked along the lake shore to examine some rocks which had been exposed when the road was cut Here were large irregularly hexagonal basaltic columns projecting from the cut surface of the hill. As they evidently belonged to the same general class of rocks as those that form the palisades of the Hudson River near New York and the basalts of the Giant's Causeway in Ireland, their presence here confirmed my suspicion that at least part of these

mountains had been formed from huge molten sheets that had forced their way up from below at the time of those great disturbances, the effects of which we had seen on the journey from Uvira. An inspection of this cut bank seemed to reveal somewhat of the mode of formation of the larger crystalline columns and of the small nodules of similar rock which had been broken up to form the road near by. For between and around the more perfect cylindrical columns were many abortive or imperfect balls of rounded form, each one arranged in its own concentric wrappings, as were also the big columns After returning home and referring to authorities on the subject, I find that the explanation is somewhat as follows. Apparently the big columns had solidified from a mass of molten matrix, which, being of large size, had cooled slowly and cracked into more or less perfect hexagonal columns. The little ovoid pieces were formed of the same material in the interspaces between the big ones The main joints that primarily broke the mass into prisms were due to cooling and shrinking. The onion-like wrappings around both big and little pieces were the result of slow weathering from the surface inward Some of the basaltic columns had evidently been removed and one very large one set up in the market-place at Bukavu.

Now that I recognized the peculiar appearance of this hill containing broken fragments of such palisade-like material, I could and did recognize similar hills in other places in these mountains, which upon inspection proved to be composed of similar material.

From such observations I was constantly attempting, but in vain, to read the riddle of the geological history of this country, although, without the special counsel of an expert petrographer, I realized that such amateur interpretations would serve at most only to stimulate interest in the following questions: Did these basalt sheets push themselves into this locality during the cycle of activity represented by the still active volcanoes north of Lake Kivu, or did they, like the Palisades of the Hudson River and the other trap sheets of New Jersey and Connecticut, belong to a far earlier age, such as the Jurassic or Triassic? And were they connected with the formation of the Great Rift valley by a system of block-faulting more or less similar to that seen in the Connecticut valley?

Another day I walked along the shore of the lake, east of the promontory, past the very orderly red parade-ground of the barracks. In this district the Belgians have planted thousands of quickly growing eucalyptus trees, a tree originally imported from Australia but now supplied in great numbers by the Botanical Gardens at Eala on the Congo River. The leaves of eucalypts, being held slanting to the sun, let the light through as do the slats of a Venetian blind, lighting up the space beneath them in a way that reminded me of the great eucalypt forests in Australia. The wood derived from them will be very useful in this woodless region, where all the hillsides are bald, especially as near by there is a large school for teaching carpentry to the natives.

After several days Raven and McGregor arrived on a camion coming from Uvira, with all the baggage necessary for our trip into the gorilla country, the rest having been stored away in a government building at Uvira. We were all eager to get off into the field, but although we had been told there would be no difficulty in hiring a camion at Bukavu, diligent inquiries at the several companies that owned them failed to reveal any except at exorbitant prices. We were then only twenty-seven miles away from the edge of the "gorilla forest," and a couple of hours should be sufficient for a camion to take us there with our three servants

and all our voluminous equipment. The porters which we would need in the mountains were to be found near the agricultural station at Tschibinda. In Africa we soon learned that long delays in transit were absolutely unavoidable. Meanwhile, however, I was free to continue my local explorations.

Soon after the arrival of our partners from Uvira I led them all out to my favorite scenes of the winding valley of the Ruzizi River, where they took moving and still pictures of the falls and rapids. These falls are wide but not very steep: they break into rapids and then make another short plunge. The natives catch fish in traps which they put out from the small island just below the falls. This island consists of an irregular mass of black crystalline rock; it divides the river in two, the rapids being on either side of it. A little way down the river is another small jagged, rocky island, upon which were many white herons and snake-birds. Doubtless the herons were attendants upon the cattle near by, while the snake-birds were resting from their fishing flights above the lake. Across the river beyond this island I saw seventeen beautiful Kavirondo cranes leisurely stalking about near the shore. There were a few long-horned cattle in this immediate neighborhood and some goats; hardly a blade of grass was in sight. But there were plenty of cattle-ticks and I soon had my first personal introduction to these pests.

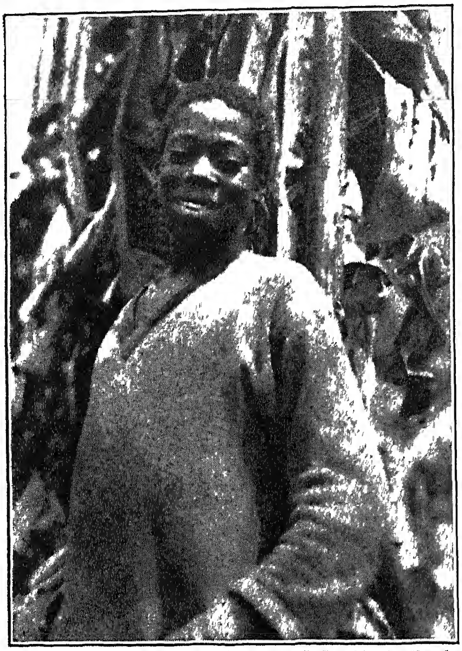
Meanwhile Dr. Engle, who had entered with enthusiasm into the game of picking up the Swahili language, had engaged a boy named Matambele, as we needed at least one more servant, and had begun to ask Matambele the names of things and check up with the Swahili dictionary and grammar. Unfortunately this had been designed to teach the classic Swahili of the standard translation of the scriptures and was different in many details from the current "Swahili" of the Tanganyika mountains.

Matambele was a comely-looking boy about sixteen years old. He had come from Ruanda, northeast of Lake Kivu, hence from the direction of the "cattle-breeding aristocracy." He had the long slender legs of the Nilotics, with the very large luminous eyes of the type which seemed to us specially numerous on the west shore of Lake Tanganyika. He had been well taught by an Englishman and all-in-all was an excellent, intelligent and willing servant, who eventually went with us as far as Stanleyville. Besides all this he proved to be very amusing in many ways of which I shall speak later.

Raven and McGregor brought three other boys with them from Uvira: the lanky cook Poussini, the short, round-faced Musafiri and the burly Behongo. Poussini was perhaps twenty-two years, the others were youths in their late 'teens.

A day or two later I went down to a little hamlet of fisher-people on the lake shore and hired a man to take me out in his canoe for the afternoon, for the purpose of paddling out to the place where Lake Kivu overflowed into the Ruzizi River. The poor chap didn't realize what he was in for when my black boy (Poussini) and I climbed into his piroque and sat down. We stayed fairly near the shore, as I knew that Lake Kivu was subject to sudden squalls.

How pleasant it was to glide along, almost without a sound! There goes a kingfisher, poising in the air before he dives; and there, with powerful strokes, a long-necked snake-bird (*Plotus*) closely allied to our American species. Many weaver-birds twitter about the long reeds on the shore and once or twice a great heron goes by. We slip past many a hill covered with plantations of coffee and sisal and millet and enter first one bay and then another. One gets the impression that the lake includes many drowned fiords. Down each fiord I look to make absolutely sure that the elusive Ruzizi River is not sneaking off somewhere from



—*Photograph by E. T. Engle*
MATAMBELE'S SMILE.

the distant end of the fiord. Finally, late in the middle of the afternoon, we pass around the great wooded promontory behind which, as I had inferred from the distant view, the Ruzizi River should be starting on its troublous journey toward Lake Tanganyika But peer as I would toward the concave lower end of this long bay, I could not see the river flowing away from it. It was getting late and the wind was against us and I wondered how long the poor knave with the paddle would hold out. Once in a while, when the breeze was stiff, I handled the second paddle myself, mostly, however, as a gesture of encouragement, as I was not used to the native method and the canoe persisted in wayward tendencies; so after a while it seemed more in keeping with my official status as commander of the craft and as a representative of the conquering and parasitic white race to let somebody else do all the work. My black boy sensibly disclaimed all knowledge of paddling and when I made him try it he amply proved his statement. Regretfully then I gave the order to return, which in spite of linguistic obstacles, was readily understood by our paddler

On the way home we stopped at a near-by island, pushed our canoe into the high reeds around the shore and climbed a long hill There I had a satisfying view of islands, mountains, lake and sky —of everything in fact but the Ruzizi River, which was meanly lurking behind a screen and would not come out to be identified. By this time I had no doubt fully convinced both the owner of the canoe and my personal boy that I was some weird kind of lunatic, with a dangerous tendency to get lost in an inconvenient place a long way from the nearest meal. However, the blacks are used to the inexplicable ways of the whites Their job was to go along and to get me back home as soon as I would let them, so neither side thought out loud, or if they did, the other side couldn't be sure there was anything personal being said.

Our canoe was under the thick bushes beneath a steep bank, while the island itself was covered with millet, which sprang back into place after we passed through it After wandering around on the opposite shore of the island, I would under these circumstances have had small chance of finding my way back directly to the canoe, as I have an exceptionally low "bump of location," but I said nothing, as I felt confident that the owner of the canoe would lead the way back for us without any hesitation, which he did So we climbed down into the canoe and started homeward in the slanting rays of the sun.

Soon our boatman spied some of his village folks seated comfortably in their boat in a quiet nook, having a bit of supper before starting out for the evening's catch. As we came near I was surprised to see a pot boiling in the middle of the canoe and a fire under it. The ingenious natives, who are masters in the art of controlling fire, had made a small fire in

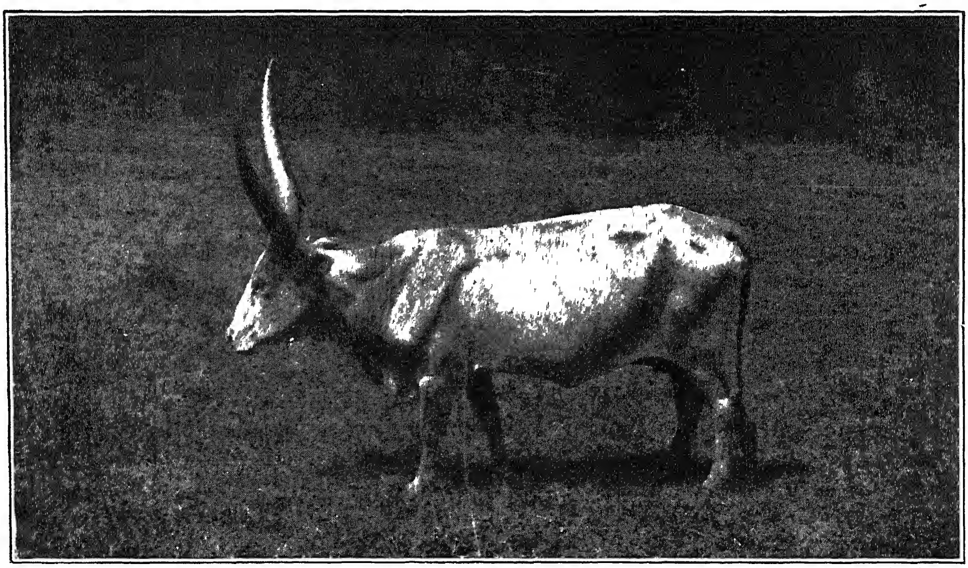
a large clay basin, which in turn rested on stones This completely protected the charred inner surface of the canoe. In addition to the fish that was in the pot, they had another fish in the canoe It was a good-sized cichlid (about seven inches long) and naturally I enjoyed examining it and working its jaws and gill-covers My boy intimated to me, however, that it wasn't worth much, as he had not yet learned that to his queer white masters the edibility of fish and other animals was only a minor consideration After a brief and strangely moderated colloquy, during which our boatman borrowed a bit of tobacco from his neighbors and puffed fiercely on his pipe, he was evidently refreshed and ready to proceed So we pushed off silently from the reeds and waved good-bye to the neighborly savages

Farther on we came to a party of old and young men in a large canoe, who were headed out toward the fishing-grounds. After a rather brief outburst of jabbering a powerful youth got into our canoe to handle the second paddle, and thereafter we fairly flew homeward in the twilight. Arrived at the steep bank near the hotel I gave our boatman pay beyond his most avaricious dreams (equal to forty-five cents) and also gave a present to the "second paddle." Out of all this I emerged with a lasting infatuation for Lake Kivu and a firm resolve to dig that old river out of his hole if it took the rest of the summer

The next day Raven and I went over the hills to the place where the weasel-like Ruzizi ought to have issued from the lake; although it tried some clever dodges, almost doubling on its tracks and hiding itself behind innocuous-looking slopes, we finally cornered it and tracked it to its lair. But even now I can't clearly see where and how it fooled me the day before.

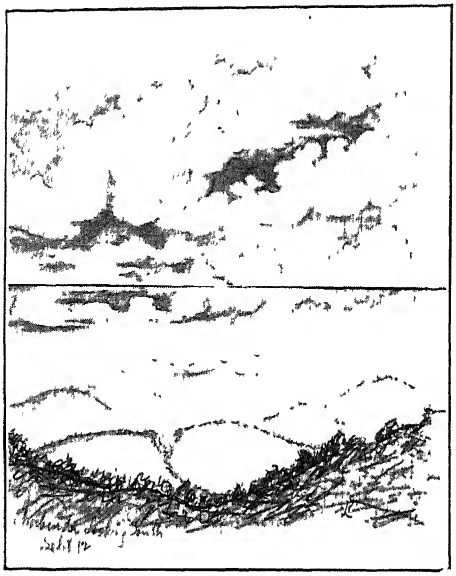
On this walk we passed through a field containing some long-horned native cattle and many of their attendant white herons. I made a few rough sketches and Raven got what proved to be an excellent view of one with enormous, nearly vertical horns and well worthy of a place beside the long-horned cattle of the Pleistocene epoch.

By this time the camion which we had been wooing assiduously for the past



—*Photograph by H C Raven*

PRIZE LONGHORN AT BUKAVU



—*Sketch from Author's Note-book*

WAVE-LIKE MOUNTAINS AND CLOUDS NEAR TSCHIBINDA CAMP

week allowed itself to be caught and loaded with our voluminous equipment, to say nothing of ourselves, four boys, the Portuguese commandant of the craft and his boy. Meanwhile we had had the great pleasure of meeting at the hotel Dr and Mrs Bingham, psychologists of Yale University, who were on their way to the Parc National Albert to study gorillas in the field.

At 4·30 on the afternoon of August third our palavers with the owner-bandit of the camion were, as we fondly thought, completed, so we bade good-bye to our kind host and hostess and to our American friends, all climbed aboard and the order was given to shove off

Our destination was Tschibinda, in the mountains northwest of Bukavu, only twenty-seven miles away as the crow flies, but with some eighteen hundred feet to climb, up to sixty-seven hundred feet of altitude. In our final choice of Tschibinda as a base for our field studies of the Mountain Gorilla we were influenced by several considerations. It was the nearest spot that was relatively accessible from Bukavu, in which Mountain Gorillas were credibly reported to be fairly common Also, Raven had received a cablegram advising us to go there, from Dr Harold J. Coolidge, Jr, who had secured two gorillas there for Harvard University. Again, the roads around Tschibinda were good, so that the difficulties of getting a four-hundred-pound gorilla out of the surrounding forests, while formidable, seemed not unsurmountable. Finally, there was an extensive agricultural experiment station at that place, where in all probability we could obtain porters and a convenient site for a camp.

So as we rumbled along the road on the shore we rejoiced that after so many trying but inescapable delays, we were at last nearing a spot where there was a reasonable hope of seeing living gorillas in the field

As far as we could see were wave-like mountains, all bare of forest but with occasional patches of banana plantations and native villages. Whenever the road cuttings were deep I could see that under the thick brown and reddish mantle of soil there were outcrops of the basaltic or nodular volcanic rock I have described above.

After a while we turned away from the lake and began to zigzag our way up long grades over the bare hills. It was very cloudy and soon after sunset the rain began to sprinkle. At last we passed some kind of settlement in the darkness and then we stopped Our wily Portuguese said that this was Tschibinda, that the rest of the way up was fearfully steep and dangerous to his camion, that our load was far too great and that we must pay him for making two trips the rest of the way in spite of the enormous price he had exacted for getting us up there. Raven explained that he had understood that Tschibinda was on top of the mountain and that we must go on. After

much palaver it appeared that this place had formerly been called Tschibinda and that the rest of the way really was steep. Finally McGregor and I and two of the boys, with half the load, got off and disposed ourselves along the roadside, while Raven and Engle went on up to the top to make arrangements for the night

McGregor and I were warmly dressed and had our raincoats, but our boys were half naked. By gesture and example I made them start a fire before the rain got too bad. But the shiftless wretches would gather only a little straw at a time and before long the fire was drowned out. There they sat huddled together, shivering like wet hens with the cold water streaming off them. By the light of our flashlights I piled the baggage up and made them crawl under it. McGregor sat on the baggage in his oilskins, but I, being somewhat dubious about spiders, centipedes, scorpions, to say nothing of big-jawed ants, and mindful of the awkward predicament of the armed knight described in "A Yankee at King Arthur's Court," chose to walk up and down like a sentry.

After an hour or so in the cold rain and darkness it was with no unfeigned joy that we saw the gleam of an approaching camion reflected in the sky; but our joy was short-lived, because our Portuguese driver, now comfortably drunk and somewhat confused and thick of speech, assured us that the road ahead was extraordinarily steep and that he would not endanger his camion and himself by taking our second load up that night. So he parked the camion by the road and we went to the settlement near by, which was named Mulungu; this was the center of the immense agricultural experiment station and here were the residence and headquarters of M. Vanderstok, the general manager. Here we met a Russian youth with a perfect English university accent, an employée of the great agricultural experiment farm. He was Mr. Ditz of Mulungu, with whom we afterward became better acquainted. It was then getting late,

—*Photograph by E T. Engle*

JUNGLE NEAR CAMP.

and he very courteously offered to get porters to remove our baggage to a safe place, as he feared some of it might be stolen if we left it there over night. He told us also that there were leopards near by and that he would not advise us to sleep on top of our baggage as we had purposed to do He then got his porters up and took us to a newly constructed storehouse, where later we spread our bedrolls on the floor and passed a very comfortable night.

Meanwhile Mr Vierstraet, who was in charge of the upper part of this experiment station, located at Tschibinda near the top of the mountain, very kindly came down in his automobile, bringing Raven. By this time we had supped sufficiently on milk chocolate, nuts and oranges McGregor went back in the car, while Raven and I remained to come up in the morning with the luggage This we did, without any special difficulty

I have related these particulars rather fully because it illustrates the kind of unexpected delays to which we were so often subjected No one, no matter with how much experience in Africa, could make safe predictions as to how long it would take to get to a given place. The only safe prediction was that the unpredictable would often happen

Utterly unexpected, to me at least, were the delightful scenes that we found on arriving at Tschibinda, near the top of the mountain. Looking down the mountain toward the east we could see one mountain wave after another, with silvery Lake Kivu in the middle distance and receding ranges on the other side. Turning toward the west, in the near background, dominating everything else, was the upper part of the mountain, clothed in a dark green forest where gorillas roamed freely In the middle distance was a jungle of vines and dense underbrush, sprinkled all over with magenta-colored morning-glories and many other flowers. Immediately around us was a beautiful garden with many flowers from Europe, in front of the pleasant residence of Mr Vierstraet and his charming family. Another pretty feature was a high mound of rocks with a meteorological station on top of it. Here and there were *Erythrina* trees, almost leafless, but with silvery yellowish trunk and branches, the latter bearing many large and brilliant red flowers, making the trees remarkably conspicuous as they stood alone in the otherwise open spaces A proud Cavirondo crane with his jaunty aigrette added another Japanese touch to the scene

In an attractive spot near his house Mr Vierstraet invited us to make our temporary camp until we could have time to choose a site even better, and Mr Vanderstok, the general manager, gave us the freedom of the whole experimental station, covering many square miles. The best feature of all was that Dr. Harold J Coolidge, Jr., had secured his two gorillas in the forest right near the house and that not long ago gorillas had been seen by the natives near by.

After a morning spent in making camp, all four of us went for our first stroll in the forest back of the house. There had been much cutting, many of the larger trees having been taken out, so that the underbrush that had sprung up was extraordinarily dense and tangled But to us, who had just come from a nearly treeless country of open plains, the Tschibinda forest seemed riotous in its luxury and color and I regretted my lack of botanical knowledge, which would give some insight into the infinitely confused struggle for a place in the sun of all these contending organisms Many birds mocked us with their calls. There was one which kept up such a monotonous and regular "Toot-toot, tooty-toot!" that many days passed before I could convince myself that the sound really was not due to some squeaky

wheel, as of a pump, perhaps connected with the agricultural station Another insisted on screeching "Ktwenty-eight, ktwenty-eight, ktwenty-eight!" in a mechanical, harsh and insistent way that seemed inappropriate and fanatical in such a jungle of anarchic form and color

But while we were still within sight of the brown fields of the farm Raven stopped and pointed to something alongside the path. A young banana plant had been bitten off and at its base was a large bolus of greenish fecal matter. "Gorilla!" said Raven, and gorilla it was. None of us needed to see a gorilla in the flesh to visualize the animal that had left this indubitable trace of its presence perhaps less than a week ago. Several times that afternoon we saw old excrements of gorillas along the path. The whole region became invested with an enhanced interest and importance; for after so many months of travel and effort we were at last (August 4th) within striking distance of our objective.

From evidence gathered on that and succeeding days it was plain that the gorillas traveled about in small groups of varying number; also that they consumed an enormous amount of vegetation, chiefly succulent stems which they cut with their teeth, often drawing the stems across their mouths, stripping off the green juicy layer and throwing down the long white stems. They made rude beds on the ground and in trees simply by sitting down and bending the branches around them; finally, it was evident that they did not stay in one locality but roamed about at random.

But gorillas were far from being "as thick as blackberries" in this or any other locality we visited, and more than two weeks of patient and persistent hunting elapsed before Raven secured Gorilla No. 1.

Meanwhile the first thing was to choose a site for our regular camp and get everything ready for the reception of our gorillas, and also to begin the work of securing the footprints and photographs of natives by means of the apparatus provided for us by Dr Morton.

(*To be continued*)

THE WORLD'S GOLD RESOURCES

By Dr. ADOLPH KNOPF
PROFESSOR OF GEOLOGY, YALE UNIVERSITY

Present Status of Production

Gold is now being mined at the highest rate in history, and the world's output for the year 1934 reached 27,475,000 ounces or, in dollars, more than 960 millions. The Presidential decree of 1934 which raised the price of gold from $20.67 an ounce to $35 has made the statistics of world output no longer directly comparable with those prior to the decree For the output of gold, unlike that of other mineral products, was always reported in dollars, because gold had a fixed price of $20.67 an ounce.

From 1890 onward the world's annual output mounted steadily till 1915, when it attained $470,000,000 Although it reached a peak in that year, the increase during the previous 10 years had been small: in other words, essentially an equilibrium between resources and production had been established. The World War then caused the purchasing power of gold to diminish. Everything the miner used increased in price, but the price of his gold remained the same. Consequently, the world's production soon began to dwindle. In the United States it dwindled steadily from the all-time peak of $101,000,000 to $45,000,000 in 1927, and world production declined to $320,000,000, almost exactly proportional to the decline in the purchasing power of the dollar.

The low point in the world's output of gold was reached in 1922, but it has been increasing continuously since In the last few years, after so many countries went off the gold standard, production has been accelerated. The world price of gold is determined in the London market, and is now the highest in the history of gold (140 shillings per ounce).

During recent years most of the world's gold has been produced by three countries: South Africa, the United States and Canada In 1934 Russia forged ahead to second place and Canada fell to fourth place The increased price of gold has reacted on production in a rather unexpected way in two of the leading countries—South Africa and Canada—it temporarily caused a decline in output, as measured in ounces; but in the rest of the world it has increased the output, and 1934 shows the record output of 27,475,000 ounces—an increase of 4,000,000 ounces over the peak of 1915

More than half the annual supply of newly mined gold in recent years has come from South Africa — from the world's greatest gold field, the Rand. In all forecasts on the future of the gold supply it must be remembered that half the annual supply is furnished by a single field, the geology and technical features of which are well known. In fact, the conditions in it are such that predictions concerning it can be made far more accurately than for any gold field in the world.

Mode of Occurrence of Gold

When we consider gold in its geologic aspect, the first striking feature is that it is widely distributed over the globe, but everywhere in small quantities If we were to put together all the gold mined since 1492, a little over 1,000,000,000 ounces, it would make a cube having an edge 38.5 feet long Half of this gold has been mined in the last 25 years

Gold occurs in so many places that the popular rule was long ago formulated that "Gold is where you find it." This explanation is thrown at one in all our gold-mining camps, and is variously at-

tributed to Job and to Mark Twain Modern geology can answer the question of what determines the distribution of gold somewhat more satisfactorily than could those authorities.

Gold occurs in two ways the world over. Most simply, it occurs as tiny flakes and grains of native metal in the gravels of streams—as placers. In this mode of occurrence the gold is easily found: all that is necessary is a pick, a shovel and a pan—even a frying-pan will serve. How easily placer gold can be traced is indicated by the fact that a tiny flake of gold worth one cent can be pounded into 2,000 flakelets and a single one of these "colors" can be caught and recognized in the miner's pan After being found, placer deposits are easily worked, requiring little capital outlay to work them profitably in the case of the richer deposits. The history of most gold-mining districts is therefore that the prospector found gold in the river and creek beds, that these deposits were soon worked out, and that attention was then directed to finding the veins and lodes from which the streams had obtained their gold.

Extraordinary mechanical ingenuity has been developed to work the leaner, low-grade placer deposits. This has reached its acme in the gold-digging dredges of California. These have attained such efficiency that they can work gravel carrying as little as 10 cents to the cubic yard. The bigger dredges had been digging as deep as 60 feet below water level, but with the new price of gold they are being reconstructed so as to dig to depths of 110 feet or more below water level.

Because of the ease with which placers can be found, all those in the civilized portions of the globe were found long ago and have been largely worked out. Only in the out-of-way places can we anticipate any discoveries. The gold output of Alaska in the past 30 years has been largely placer; and the recent increase of the Russian output is chiefly from placers, though here again it is not so much owing to new discoveries as to the results of the energetic mechanization and modernization of equipment.

A very up-to-date development of a placer field has recently been accomplished at the Bulolo field in New Guinea To open up this field would have required the building of a road that would not only have been 90 miles long but also would have had to cross a mountain range 4,000 feet high To save this expense it was decided to bring in all equipment by airplane. Pieces up to 7,000 pounds were transported, and two dredges are now operating very successfully.

To sum up the placer situation: the world's gold placer deposits are nearly exhausted, and at present they supply only 10 per cent. of the world's new gold.

Veins and Lodes

The bedrock sources of gold—the veins and lodes—are now the mainstay of the gold-mining industry and hold the bulk of the reserves.

Gold veins occur in the earth's crust only in those portions in which in the geologic past there has been igneous action. By igneous action is meant the rise of molten rock-matter from deep in the earth to higher levels in the crust or to its eruption at the surface. During many of the so-called revolutions in the earth's crust, which have occurred from time to time during the long span of geologic time, the strata of certain long narrow belts are bent and closely crowded together so that they stand vertically. Enormous masses of molten granite are generated: in our own Sierra Nevada, during the mighty revolution near the end of Jurassic time, say a hundred million years ago, thousands of cubic miles of molten granite worked their way upward into the higher levels of the crust. As these masses cool and

solidify they give off their dissolved gases, which rise toward the earth's surface and eventually appear there as hot springs. If they carry gold, this gold is deposited on the way up, along with quartz, thus forming the most common type of gold deposit, the gold-bearing quartz veins. A series of more or less closely spaced parallel veins, together with the intervening rock matter, is termed a lode Such veins and lodes occur in the borders of granite masses or in the rocks surrounding the granite masses. Practically it has been found that veins thus formed supply most of the world's gold Many of them are remarkably persistent in depth, and man has gone down on these veins into the earth's crust as deep as 8,000 feet vertically below the surface—far deeper than in his quest for any other metal.

Spectacular gold deposits have sometimes been formed in connection with the outbreak of molten rock matter at the earth's surface; in short, in connection with volcanic outbursts. These deposits generally give out at shallow depths, at 1,000 feet or less. The distinction between these veins and those formed in connection with deep-seated igneous rock is therefore of very practical interest.

It is an interesting fact that most of the world's great gold mines are in Pre-Cambrian rocks—in South Africa, in Ontario, in India, in Brazil and in our own greatest gold mine, the Homestake in South Dakota.

The gold in sea water is of perennial interest. When in 1921 the Reparation Commission demanded of Germany 132 billion marks (=50,000 tons of gold) it seemed fitting, as Haber says, for the chemists to see whether the immense reserve in the ocean might not be made available. Arrhenius in 1903 had estimated the gold content as 6×10^{-6} gm. per kilogram. As the result of his careful work Haber reduced this to 1/1500 of Arrhenius' estimate, which is far below the limit of commercial availability. The gold was found to be present in the sea mainly in coarsely dispersed form, *i e*, not in solution but entangled with suspended material and the plankton. Haber predicted that the deep-sea sediments will therefore be relatively rich in gold

Recently a minute amount of metallic gold has actually been isolated from sea water as a by-product in the recovery of bromine, but at a cost of fifty times its value

Resources of the United States

The gold resources of the United States are well known, and we can therefore make some confident predictions about their future output. The more important placer deposits have been found and are largely worked out. There is only one important exception the Tertiary auriferous gravels of the Sierra Nevada—the dismembered relics of a system of dead rivers. About one billion dollars are locked up in these gravels, but the working of these gravels has been practically suspended since the Anti-Debris legislation of 1884 There these auriferous gravels have lain the past fifty years, an irresistible temptation to the miner. I have wondered how long before he would overcome the legal and other obstacles that hinder him from working these deposits. Surely enough laws have recently been passed by the legislature of California, conferring the power of forming placer-mining districts in analogy with irrigation districts, with the right of eminent domain. These placer-mining districts will build concrete restraining dams to impound the gravel tailings from the gold washings, and there is no doubt that California is in for a revival of this form of hydraulic placer mining

How well the forty-niners and their successors depleted the present streams of their gold is shown by the recent experience of the hordes of unemployed

who have gone into the California hills to try their luck at placer mining. During 1932 and 1933 there were 12,000 to 15,000 placer seekers, but their average reward was $40 apiece for the season of 1932.

The last finding of a major gold field in the United States was the Cripple Creek district, Colorado, as long ago as 1890. The veins here are in the throat of an old volcano and to date have yielded $400,000,000. The present yearly output has fallen to a fraction of what it was at zenith, in 1900, but is now on the upgrade.

Early in the present century spectacular gold finds were made in Nevada, notably at Goldfield. Here in the desert sprang up almost over night a full-fledged city, and for a few brilliant years Goldfield had the most productive gold mine in the world. The district produced about $100,000,000 and was then nearly worked out.

The most productive gold mine in the United States is the Homestake, in the Black Hills of South Dakota. Long famous as a highly successful enterprise on low-grade ore ($3 to $4 a ton), the grade of its ore was raised to $6 to $7 a ton by the application of geology to the problems of mining and then to $10 to $11 a ton by the new price of gold. It is now paying dividends at the rate of $3 a month.

Alaska has yielded $400,000,000 since 1880, but does not seem destined to give us a major gold field. The most notable feature of its gold-mining industry is that in the Alaska-Juneau mine it has the premier low-grade mine in the world. At this mine has been achieved the unprecedented feat of profitably mining ore carrying only one pennyweight to the ton. Although this great technical achievement is not likely to be repeated at many places, owing to a combination of favorable circumstances at Juneau, still it remains a goal at which to aim.

It appears that no major field has been discovered in the United States during the last 30 or 40 years, and the finding of another in the future is unlikely. However, the new price of gold has converted much marginal and submarginal material into ore, and it is probable that the value of the domestic output will in a few years exceed that of the zenith year (1915)—$101,000,000.

In "Gold Resources of the World" it was estimated that the output of the United States from 1928 to 1950 will be between 35,000,000 and 108,000,000 ounces. It now appears that the output will more probably reach the maximum than the minimum figure.

Future of the Rand

The Rand is the world's greatest gold field. It has yielded more than $5,000,000,000 on the old valuation of gold—nearly $9,000,000,000 on the new. In recent years it has been supplying more than half the world's new gold. Another way of illustrating the Rand's importance is that 29 of the 43 leading gold mines of the world are in the Rand. In any forecast of the future of gold, the future of the Rand is the most important factor.

The gold occurs here in a way that is nearly unique. It occurs in what was once a thin bed of gravel that had been spread horizontally over the earth's surface. In the course of time the formation in which this bed is intercalated was bent deep down into the earth's crust—into a syncline, as the geologists say—and the gravel became cemented to a hard rock, to a conglomerate. During the 50 years of mining, the conglomerate bed has been followed ever deeper into the crust. More than 220 square miles of the bed, averaging 2 feet in thickness and 7 pennyweight to the ton, have been mined. Not fabulously rich, it will be seen; its great output is the result of technical efficiency. Depths of 8,200 feet have now been attained.

Mining at such great depths entails

special technical problems. The two most important are the increase of temperature with depth and the danger of rocks bursts. A depth of 7,500 feet was regarded a few years ago as the economic limit of mining, but already some of the mines have reached a depth of 8,200 feet. Fortunately the Rand is favored by an extraordinarily slow rate of increase of rock temperature—1° F. for every 212 feet of depth. But at 8,000 feet depth that means a temperature of 97°. That temperature, coupled with the high humidity (due to free use of water to keep down silicosis-producing dust), causes fatalities by heat stroke. Even for the "acclimated" worker it greatly impairs working efficiency: to about one half, I should say. Consequently, the Robinson Deep mine is now building the largest air-conditioning plant in the world in order to supply refrigerated air to the bottom levels of the mine.

An even stronger obstacle to mining at great depths than the difficulty of keeping the temperature down is the difficulty of supporting the workings. At great depths the rocks, especially the more brittle kinds, develop the dangerous feature of spalling off fragments. Pieces fly off with explosive violence, not only causing fatal accidents but also making it difficult to keep open the workings. It is probable that the difficulty of support of the workings rather than the problem of ventilation will determine the ultimate depth of mining.

A few years ago it was generally accepted that the Rand would be practically exhausted by the year 1950. The high price of gold has, however, greatly altered the complexion of things. It has doubled the prospect of the life of the mines now working and has made profitable vast quantities of submarginal ore. The immediate effect of the high price of gold on production has, however, been the opposite of what might on first thought have been expected. The amount of ore mined in 1933, it is true, increased, but the yield per ton (5.84 pennyweight) decreased, so that, although the value of the output was larger, the number of ounces of gold produced was smaller. By August, 1934, the average content had decreased further still to 4.85 pennyweight a ton. In other words, lower grade ore is being mined, and the mines are thus conserving their resources. Dividends, however, gratifyingly increased by 50 per cent. Taxation, on the other hand, has increased 440 per cent. since 1932. As long as present economic conditions persist, the exhaustion of the Rand is so far off as not to be a matter of much present importance.

Conclusions

The gold resources of the world are large, but they can not be measured with any approach to accuracy. Only the amount of gold in some of the placers can be roughly appraised. The placers of the United States are mainly in California and Alaska; for the remainder of the world, chiefly in Siberian Russia. From the Russian placers, as the result of the present energetic campaign of the Soviets in mechanization and modernization of equipment, we may expect to see a steadily increasing output.

It may be of interest to consider some earlier forecasts of the future of gold. During the world war the gold production began to fall alarmingly. An able committee appointed in 1918 by the Secretary of the Interior to study the gold situation in the United States reached the conclusion that "the output of the world seems to have passed its zenith and to be on the decline." This conclusion held for four years. In 1922, however, the world output reached a low, and from then on it began to increase. In spite of the recovery, however, most authorities remained highly pessimistic as to the future of gold because of their belief in the early exhaustion of the

world's principal deposits. Kitchin in a report to the League of Nations in 1930 had the astonishing courage to forecast each year's output till 1940. For 1934 he estimated a yield of $403,000,000. Loveday in a later report to the League of Nations thought Kitchin's figures too optimistic and estimated an output of $390,000,000 in 1934 and $314,000,000 by 1940. Actually the 1934 output was $570,000,000 at $20.67 an ounce, or $962,000,000 at the new price of gold.

It is the new price of gold that has completely changed the situation. In all countries of the world the immediate effect has been to raise submarginal and marginal gold-bearing material into ore, and in all countries, except the Rand and Ontario, the output in ounces has increased. In those two regions the large mines preferred to mine lower grade ore and save the better ore for the future. But much capital is pouring in, and in two or three years the production from new mines and milling plants will swell the output.

Improvements in mining methods and metallurgy will aid to some extent, although these have already been brought to a state of very high efficiency. Improvements in transportation facilities, as exemplified by the airplane, which has accelerated the opening up of such inaccessible regions as the interior of New Guinea and the area of 2,000,000 square miles of Pre-Cambrian rocks north of the Great Lakes, known as the Canadian shield, will lead to new discoveries. Rich placers can not be expected to be found, but lodes will be found, which will at least counterbalance the exhaustion of those now being mined. Geophysical methods of prospecting will help in finding new deposits, as brilliantly demonstrated by the discovery of the first-class deposit at Boliden under the glacial drift of northern Sweden.

The history of gold production during the last twenty years appears to demonstrate that the main factor in determining production and reserves is the purchasing power of gold. We may therefore anticipate that the world output in a few years will exceed $1,000,000,000, and will remain at that figure for some years. When it reaches that figure, an equilibrium, as it were, will have been attained between production and the present purchasing power of gold, just as earlier, in the period culminating in 1915, an equilibrium between production and purchasing power of gold at that time had been established. If and when the purchasing power of gold declines, the world output of gold will decline with it.

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THE FIRST OFFICIAL PHOTOGRAPHER

By CHARLES MACNAMARA
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NOWADAYS the official photographer is such an indispensable member of every well-organized exploring party that it is interesting to look back to the first of these important personages and learn something of his experiences and adventures. His name was Solomon N. Carvalho, and he was attached to Colonel John Charles Fremont's fifth exploring expedition to the West in 1853–54, the object of which was to discover practicable passes for a railroad through the mountains at the sources of the Rio Grande. This great explorer's expedition for the same purpose five years before had ended in disaster without attaining its aim. A guide led the party astray, and Fremont, caught in the snow, lost all his equipment, and several of his men perished. Some of the starving survivors were driven to cannibalism before the party reached safety in the settlements of Southern California.

The expedition of 1853–54 was intended to retrieve this failure. Avoiding the fatal route where the guide went wrong before, this time Fremont found the hoped-for passes, which, however, have never been used for a railroad. But again the explorers suffered great hardships, and it was a wretched company that came out of the mountains into a settled valley in Southern Utah and straggled into the little Mormon town of Parowan.

Except for a couple of letters written by Fremont to the *National Intelligencer* in 1854, the only known account of this expedition is in the book by Carvalho published in 1857. The title, spaciously composed in the good old-fashioned manner, promises some exciting reading, but indicates nothing of photographic interest:

Incidents of Travel and Adventure in the Far West; with Col. Fremont's Last Expedition across the Rocky Mountains: including three month's residence in Utah, and a perilous trip across the Great American Desert, to the Pacific. By S. N. Carvalho, artist to the expedition. New York: Derby & Jackson, 119 Nassau St. Cincinnati·—H. W. Derby & Co. 1857.

But it turns out that the author with the Portuguese name (though he was a born American) besides being an artist was also a daguerreotypist, and it was chiefly in that capacity that he accompanied the expedition.

Carvalho tells us nothing of himself previous to joining the expedition, but some little information may be gleaned from casual remarks in the course of his account. Thus it appears that in his younger days he lived in Charleston, and that at the time of the expedition he had a wife and children, and his parents were still alive. His preface is dated at Baltimore, and he is listed in the directories of that city from 1851 to 1860 as an artist and in charge of a daguerreotype studio. But it was in New York that he met Colonel Fremont, whether by chance or appointment does not appear. At this time of his life Fremont was a great national hero—three years later he was nominated for the presidency—and Carvalho was evidently one of his most devoted worshippers. The daguerreotypist had had no experience of life in the open, and was obviously much more at home in the velvet jacket and fez of the "studio artist" than in the dress of a frontiersman: "I had never saddled a horse myself. My sedentary employment in the city, never having required me to do such offices"—a quotation which gives a foretaste of his style and the occasional peculiarity of his punctua-

tion. He foresaw all the hardships and risks of the journey clearly enough, yet such was his admiration for Fremont that, much to his own surprise, he joined the expedition.

On the 22d August, 1853, after a short interview with Col. J. C. Fremont, I accepted his invitation to accompany him as artist of an Exploring Expedition across the Rocky Mountains. A half hour previously, if any one had suggested to me, the probability of my undertaking an over land journey to California, even over the emigrant route, I should have replied there were no inducements sufficiently powerful to have tempted me. Yet in this instance, I impulsively, without even a consultation with my family, passed my word to join an exploring party, under command of Col. Fremont, over a hitherto untrodden country, in an elevated region, with the full expectation of being exposed to all the inclemencies of an arctic winter. I know of no other man to whom I would have trusted my life under similar circumstances.

Carvalho was rated as an artist, and he took paints and brushes with him, but his principal duty was to be "making a panorama of the country, by daguerreotype process, over which we had to pass"; and the next ten days after his engagement were spent in getting together the necessary materials. Although rivaled by Fox Talbot's calotype, and due for extinction in a year or two by Scott Archer's wet collodion process, daguerreotypes were still exceedingly popular. In London at this date the charge for a "quarter-plate" ($3\frac{1}{4}$ by $4\frac{1}{4}$ inches) Daguerre portrait was fifty shillings, and for a "half-plate" ($4\frac{3}{4}$ by $6\frac{1}{2}$ inches) eighty shillings. Carvalho is exasperatingly silent on the details of his equipment and work, and says nothing of the size of his plates nor which of the several modifications of the process he practiced. Perhaps such shop-talk was beneath him. But it will be recalled that the Daguerre process consisted essentially in exposing a highly polished and meticulously clean silver plate—usually silver plated on copper—to the vapor of iodine until the silver surface turned a bright golden yellow. This iodized plate was exposed in the camera, the first working methods requiring an exposure of five to thirty minutes, reduced by later methods to as many seconds. Development was effected by subjecting the exposed plate to the fumes from mercury heated in a saucer by a spirit lamp. The image—a positive one—appeared in about twenty minutes, and was fixed in a solution of hypo, the chemical still familiar to all photographers. The plate was washed by carefully running distilled water or boiled and filtered rain water over it. The image was sometimes toned with gold, and most of the daguerreotypes still in existence were so treated. The picture was exquisitely fine, but so tender that it would not stand the slightest touch, and had to be protected with a cover glass. Although daguerreotypes were the first actual pictures produced solely by physical and chemical means, in short the first real photographs, yet the process proved to be a dead end in photography, and the science developed in quite another direction.

And here it may be noted that it was only by a narrow margin that Carvalho gained his distinction as the first expedition photographer. For the next year (September, 1854) an Englishman, Roger Fenton, joined the British forces in the Crimea as the first war photographer. His process was wet collodion, just coming into general use, and his equipment (bulky apparatus was a leading feature of the "wet plate" method) included a covered van and four horses, and 36 large chests containing two large and two small cameras, 700 glass plates of four different sizes, a portable still and stove, chemicals, printing frames, baths, dishes and sundries. Whatever Carvalho's apparatus may have been, it certainly was nothing as ponderous as that.

As this was the first time that daguerreotypy was to be attempted on an exploring expedition, Carvalho's profes-

sional friends were doubtful of his success.

> Buffing and coating plates, and mercurializing them, on the summit of the Rocky Mountains, standing at times up to one's middle in snow, with no covering above save the arched vault of heaven, seemed to our city friends one of the impossibilities—knowing as they did that iodine will not give out its fumes except at a temperature of 70° to 80° Fahrenheit.

How he overcame the "impossibilities" Carvalho does not disclose, but he intimates that he was entirely successful, although at the cost of severe suffering. He belittles neither his achievements nor his hardships, and no doubt both were real enough.

> I shall not appear egotistical if I say that I encountered many difficulties, but I was well prepared to meet them by having previously acquired a scientific and practical knowledge of the chemicals I used, as well as of the theory of light: a firm determination to succeed also aided me in producing results which to my knowledge have never been accomplished under similar circumstances.
>
> While suffering from frozen feet and hands, without food for twenty-four hours, travelling on foot over mountains of snow, I have stopped on the trail, made pictures of the country, repacked my materials, and found myself frequently with my friend Egloffstein . . . and a muleteer, some five or six miles behind the camp, which was only reached with great expense of bodily as well as mental suffering. The great secret, however, of my untiring perseverance and continued success, was that my honor was pledged to Col. Fremont to perform certain duties, and I would rather have died than not have redeemed it. I made pictures up to the very day Col. Fremont found it necessary to bury the whole baggage of the camp, including the daguerreotype apparatus. He has since told me that my success, under the frequent occurrence of what he considered almost insuperable difficulties, merited his unqualified approbation.

Carvalho's relation is more or less disconnected; events are not recorded in the order of their happening and dates are mostly wanting. This article will not attempt a continuous account of the expedition, but will touch principally on incidents of photographic concern, and will pass over buffalo hunts, prairie fires, search for lost horses, contacts with none too friendly Indians, deep snows and cold weather in the mountains, shortage of food and such like occurrences usual to Western travel of the day.

Carvalho left New York on September 5, 1853, and joined Colonel Fremont and others of the party at St. Louis. Thence they traveled by steamboat up the Missouri to the mouth of the Kansas, where the rest of the party was in camp awaiting them.

Now appears a "Mr. Bomar, the photographist," who seems to have been engaged in addition to the daguerreotypist, or at least had been taken on trial. The two craftsmen found quarters in a hotel, and proceeded to put their respective apparatus in working order. Carvalho says "Mr. Bomar proposed to make photographs by the wax process, and several days were consumed in preparing the paper, etc."

The wax process was an improvement on Fox Talbot's calotype process, which, as is well known, differed fundamentally from daguerreotypy in producing a negative from which any number of positive prints could be made—the leading principle of all modern photography. In calotype, sheets of paper were washed over with a nitrate of silver solution, dried, immersed in a solution of potassium iodide and again dried. The paper so prepared could be stored for future use. Before exposure in the camera the paper was brushed over in the dark room with a mixture of silver nitrate, acetic acid and gallic acid. It could be exposed wet or dry, and exposures ran from fifteen seconds to twenty minutes. Development was with the gallo-nitrate mixture used in sensitizing, and the negative was fixed in potassium bromide or hypo. Printing paper was prepared in the same way as the negative paper. The wax process introduced some slight variations in the chemical treatment, but the principal difference was the preliminary wax-

ing of the paper to reduce grain and facilitate printing. For some years the process competed with daguerreotype, but popular taste had been formed on the beautifully fine Daguerre image and did not take readily to the rather coarse and grainy calotype picture.

Although its chemistry was a little more complicated than that of daguerreotypy, it is likely that the wax process with its hardy, inexpensive negative, capable of yielding any number of prints, would have been a better method for the expedition than the daguerreotype with its single, unreproducible, costly and delicate picture. But Carvalho, proud of his skill and jealous for his process, was not going to let any mere photographist supplant him, and he took steps to secure his position.

> I was convinced that photographs could not be made by that process as quickly as the occasion required, and told Col. Fremont to have one made from the window of our room to find out exactly the time. The preparations not being entirely completed, a picture could not be made that day; but on the next, when we were all in camp, Col. Fremont requested that daguerreotypes and photographs should be made. In half an hour from the time the word was given, my daguerreotype was made; but the photograph could not be seen until the next day, as it had to remain in water all night, which was absolutely necessary to develop it. Query, where was water to be had on the mountains, with a temperature of 20° below zero? To be certain of a result, even if water could be procured, it was necessary, by his process, to wait twelve hours, consequently, every time a picture was to be made, the camp must be delayed twelve hours. Col. Fremont, finding that he could not see immediate impressions, concluded not to incur the trouble and expense of transporting the apparatus, left it at Westport, together with the photographer.

The last phrase betrays a certain satisfaction. Yet when the rejected photographer later heard all that happened to the expedition, the satisfaction must have been all his.

Colonel Fremont's reason for deciding against the wax process does not seem a valid one. There was no instantaneous need for the pictures. They were intended to illustrate the future report of the expedition, and it would not have mattered if their completion had been delayed for months, to say nothing of twelve hours. And to acquit Carvalho of intentional misrepresentation, it must be supposed that he did not understand the wax process when he asserts that it would have been necessary to delay the camp twelve hours every time a photograph was made. It is not on record that the fully sensitized paper would keep indefinitely, but it was good for some days at least. The "wax processer" could prepare his paper at night, and have it ready for use during the next few days as required. The negative, again, could be developed at night; and prints, of course, could be made at any time, months or years later. However, the photographer was discarded, and dependence for pictures was now all on the daguerreotypist.

About September 21 the explorers set out by pack train up the course of the Kansas River, and after traveling a week or so, encamped near Salt Creek until the end of October, awaiting the return of Colonel Fremont from St. Louis, where he had been obliged to go for medical treatment.

Carvalho's troubles began in the first few days of travel. Very early the baskets holding his apparatus were broken and rendered useless. Colonel Fremont may have held the daguerreotypist in high esteem, but the mule drivers emphatically did not. They evidently regarded him and his unwieldy baggage as common nuisances, and it was more than likely that they had broken the baskets in the hope that the apparatus would be abandoned.

Carvalho managed to find box covers enough to make cases for his materials, but he says—almost unbelievably—that the expedition lacked such elementary

tools as a saw and a hatchet. To put the cases together, he and a friend had to ride ten miles with the boards to a frontier village, where they borrowed the necessary tools from a blacksmith. Here they shaped the boxes and reinforced the joints with rawhide. They returned to the camp each with a huge box before him on the saddle. Carvalho's style is much too genteel to permit a literal statement of what the mule drivers said when they saw him coming back with the boxes. What we may be sure was the full Rabelaisian flavor of their remarks is entirely wanting in his polite record:

> Nobody in camp knew my errand to town, and I shall never forget the deep mortification and astonishment of our muleteers when they saw my boxes. All their bright hopes that the apparatus would be left were suddenly dissipated.

But the muleteers were not yet defeated. Later on they took to "accidently" forgetting the apparatus on the trail. The tin case containing the indispensable buff for polishing the silver plates Carvalho twice found dropped on the road. The buff lost, all the rest of the apparatus was useless. Another time the keg of alcohol was missing, and when discovered back on the trail, half its contents was gone. But Carvalho's fortitude remained unshaken, and he prides himself on his perseverance and watchfulness in preventing the loss or destruction of his equipment.

On Colonel Fremont's return at the end of October the march was continued up the Kansas. The water in this river was too turbid to wash the delicate Daguerre plates, and final finishing of the pictures had to be deferred until the crystal streams of the Rockies were reached. Immense herds of buffalo were encountered all along the way, and when crossing the divide between the Kansas and Arkansas rivers, Carvalho tried to photograph some of them in motion, but failed. The day of instantaneous photography had not yet arrived. A Cheyenne village on the Arkansas afforded many pictures, and the daguerreotypist won great fame among the Indians by changing their brass bracelets and rings in an instant to glittering silver by wiping them over with mercury. And when he demonstrated "fire water" by lighting with a match some of the alcohol he used to heat his mercury, he was universally hailed as a big medicine man.

They pursued their way up the Arkansas, eventually branching off to follow a tributary, the Huerfano, in the present state of Colorado. Here Carvalho was instructed to make several views of a remarkable sugar-loaf hill, Huerfano Butte. For this purpose he remained behind with four men and several pack animals. By the time the views were taken the main body was four hours ahead, and Carvalho's party failed to reach them that night. To balance the daguerreotype boxes, the mules had been loaded with all the buffalo robes and blankets of the camp, so the party was well supplied with bedding, but they had nothing to eat as all the food was with the main body. The weather turned intensely cold, and both parties passed a bad night, one suffering from hunger and the other from cold.

It was not far from here that the former expedition had taken the wrong route with such disastrous consequences. Colonel Fremont pointed out the fatal place, and Carvalho took pictures of the distant scene. Making their way through the Sandhill pass into the San Luis valley, the explorers came on the last deer they were destined to find on their journey. They stopped several days to cure the venison, but the provision proved to be not nearly enough to see them through the mountains. They crossed the head waters of the Rio Grande and, winding through the hills, presently they reached waters flowing to the Pacific. A violent rain storm, the only really heavy rain they experienced in six months'

travel, soaked all the camp equipment—except the daguerreotype apparatus. The inevitable Carvalho with "careful precaution" always secured it against rain or snow. But he neglected to secure his own person, and he was so drenched that he gave himself up to gloomy and somewhat confused reflections:

> It is a happy thing for us that futurity is impenetrable, else my fond and fragile friends at home would endure more anguish than they do now, in their ignorance of the situation their husband and son is placed in.

The question arose of taking views from the top of a steep and rugged mountain. Colonel Fremont thought it would be impossible, as the ascent was too steep for the mules, and he regretted missing the fine panorama that might be obtained from such a vantage point. Carvalho said that with two men to carry his apparatus he would try. The colonel pointed out the immense difficulties. Carvalho insisted. Then Fremont said he would go himself with the daguerreotypist. Such condescension on the part of the leader touched Carvalho so deeply that he says:

> . . . it induced my unwavering perseverance in the exercise of my professional duties subsequently, when any other man would have hesitated and probably given up, and shrunk dismayed from the encounter.

Three hours' hard climbing brought them to the summit, and Carvalho was awed by the magnificence of the view. Plunged to his middle in snow, he made a panorama of the mountains, while Colonel Fremont took thermometer and barometer readings and examined the rocks. They descended to the camp without untoward incident. Colonel Fremont's action proved, says Carvalho, "that he would not allow his men or officers to encounter perils or dangers in which he did not participate." It may also have proved that the colonel wished to avoid a search for a tenderfoot daguerreotypist lost in the mountain snows.

As we have seen, Carvalho asserts that he continued to take views up to the day the baggage was abandoned, yet after this incident no further mention is made of photography. Dates are wanting in the story, but the party was now traveling in the depth of winter, their way through the mountains was deeply encumbered with snow, and the temperature was at times as low as 30 degrees below zero. The fast-flowing, ice-edged rivers were crossed with great difficulty. Provisions became very scarce and they had to kill their horses for food. The assistant engineer, Oliver Fuller, died from exhaustion At last the baggage was cached in the snow and the men were mounted on the pack animals. After much suffering, early in February, 1854, the explorers finally reached the little town of Parowan in Southern Utah, and were very hospitably received by the Mormon inhabitants. Carvalho describes his pitiable condition, which was typical, he says, of all the others:

> I was mistaken for an Indian by the people of Parowan. My hair was long, and had not known a comb for a month, my face was unwashed, and ground in with the collected dirt of a similar period. Emaciated to a degree, my eyes sunken, and clothes all torn to tatters from hunting our animals through the brush. My hands were in a dreadful state; my fingers were frost-bitten, and split at every joint; and suffering at the same time from diarrhoea and symptoms of scurvy, which broke out on me at Salt Lake City afterwards.

After two weeks' rest at Parowan, Colonel Fremont and most of the others crossed the Sierra Nevada and continued on their way to California. But the daguerreotypist was not strong enough to go with them, and he journeyed to Salt Lake City in a wagon ("I had to be lifted in and out like a child") with a large company of Mormons on their way to "Conference." In his two months'

stay at Salt Lake City he received many kindnesses from the tall imposing president, Brigham Young, whose portrait he painted, as well as the portraits of some of the "Apostles." And here he grew so stout and able-bodied that his weight increased by 61 pounds.

On May 6, 1854, he set out for California with a party of 23 Mormon missionaries headed by Parley Pratt, the Mormon "Isaiah," and bound for the Sandwich Islands. This journey included the "perilous trip across the Great American Desert" featured in the title; but beyond the loss of a few horses nothing particular happened. Arriving at San Bernardino on June 9, he traveled by easy stages to San Francisco. How he got home from there he does not reveal. Here his story ceases, and the first official photographer fades out of history.

What happened to his hard won pictures is not definitely known. After mentioning their burial with the camp equipment, Carvalho says nothing more about them. Fremont, in his letter to the *National Intelligencer* dated the day after he reached Parowan, writes:

> Until within about 100 miles of this place we daguerreotyped the country over which we passed, but were forced to abandon all the heavy baggage to save the men and I shall not stop to send back for it. . . .

Yet somehow the plates were salvaged, for Allan Nevins states in his "Fremont: the West's Greatest Adventurer" that in the summer of 1854 Fremont was back in New York "working in the studio of the photographer Brady to assist in finishing the Daguerre plates taken by Carvalho." The plates, however, were never published. Professor Nevins says in a letter to the writer: "I believe he [Fremont] contemplated a careful history of the fifth expedition illustrated by the plates, but its ill success and other circumstances forbade this."

All Fremont made public on the expedition were the two newspaper letters already mentioned. The single illustration in Carvalho's book is not a reproduction of one of his own pictures, as might be expected, but a woodcut after a drawing signed "J. Dallas." It purports to show Fremont and Carvalho making astronomical observations. Of late years several searches have been made for the plates, but no trace of them has been found. Their certain fate is in doubt, but Daguerre pictures were so fragile that it is only too likely the plates of the undismayed Carvalho perished long years ago.

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ETHIOPIAN—THE OLDEST LANGUAGE

By Dr. JOHN P. HARRINGTON

SMITHSONIAN INSTITUTION

ETHIOPIAN is the oldest language in that it has departed the least in its forms from the original proto-Semitic. Even the Hebrew in which the Bible is written has gone a long road of development beyond even the modern Ethiopian. Hidden away in the African Alps, this old language has still survived, uncorrupted by the centuries.

Let us take, for instance, the name of the letter *a*. This letter in its capital form still preserves to-day very much of its original pattern, which was that of a crude figure of the head of an ox. The descending strokes at the bottom of capital *A* are the horns of the head of the ox. Ancient Egyptian has a very similar symbol. The natives of central Celebes have similar carvings of the head of the water buffalo on the beams of their houses. Now the name of this letter and of the ox is in the primitive Semitic, spoken 5000 B. C., *alf*. In ancient and modern Ethiopian the name *alf*, ox, is still on the tongue of the people. But in the Hebrew of the Bible it is already *aalef*, ox, the word having been distorted into two syllables and starting with a lengthened vowel.

So also with *b*, the second letter of the alphabet. The name of the letter means house, and the form of the letter is a picture of a house. The ancient proto-Semitic word for house was *bayt*. Ancient and modern Ethiopian also has *beet* or *byeet*, while the Hebrew, even the Hebrew of the Bible, has already changed the word to *beeth*, with *th* instead of *t*.

The writing of ancient and modern Ethiopian is as primitive and enticing as the language itself. Only here they have improved on the ancient Semitic alphabet, which had symbols for consonants only. If vowels were added in writing Hebrew, they were added outside the contour of the letter as separate dots and dashes, much as in some systems of shorthand. The overdotting of Hebrew with vowel points is well known. At the time the King James version of the Bible was being made, certain scholars and clergymen were in conference at Oxford University. One eminent scholar declared that a certain text on the table before him was letter perfect, or better said, "dot-perfect." They adjourned for lunch. When the clergymen returned an hour and a half later, an excessive dotting was discovered on the text. Great was the perplexity, until one of the members suddenly discovered and exclaimed: "A fly did it." Arabic writing is also full of dots. These dots and dashes are bothersome to make and often break off in printing, as is well known to printers. The inventive genius of the Ethiopians, who started with the same alphabet as the Hebrews, devised, however, the mere adding of ticks, loops, etc., connected with the consonant letters at their various corners, sides, tops, etc., to indicate the various vowels that follow. The Ethiopian system is as compact as it is legible, when one gets used to it, and does away with all the cluttering dots of Hebrew and Arabic. The Ethiopian letters are placed to read from left to right, just as in English, and a nice big colon is put at the end of every word, which keeps the words neatly apart in the manuscripts.

Ethiopia is the oldest Christian country, having been completely converted to Christianity at a date somewhere after 200 A D. The Ethiopians were a thoroughly Christian country under a heavy priesthood at the time when Italy was persecuting Christians under the Roman emperors. The Ethiopian literature is from the earliest times rich, consisting of Bible translations, prayerbooks, liturgies and a wealth of documents of every description. Ancient Ethiopian was spoken down to 1600 A. D., when it broke up into the modern dialects. These modern dialects are still the most primitive Semitic languages, and the closest thing existing to ancient Egyptian, Egyptian's direct descendant, Coptic, having become extinct.

Ethiopian has been called from the first *lesawa* (tongue or language) *geghez* (of the free), that is, the language of the free. Why this name was applied has never been known, but it has been the common and only name of the language through all the ages. It shows that the Ethiopians have been a freedom-loving people throughout all the five thousand years of their unbroken existence as an independent nation.

The Ethiopian language is easy to pronounce and its words are easy to remember. It is sonorous. It is accented mostly on the next to the last syllable.

We shall give first some words in the old classical Ethiopian language to show how they stick with one. The Biblical word is in almost every instance similar but more corrupted. Doubling of vowels is here used to indicate long vowels.

Kitaab, book; *salaam,* health; *'aalam,* world, glory; *gabaar,* a workman; *naggaasii,* king, emperor; *mehraam,* temple; *manbar,* throne; *maslem,* Moslem; *barhaan,* light; *'aalamaawii,* earthly, worldly; *kawaanee,* being, existence; *wagr,* hill; *saittaan,* Satan; *kookab,* star; *Amlaak,* God; *manfas,* spirit; *qasiis,* priest; *xebest,* bread; *ana,* I; *nahhnu,* we; *ahhaduu,* one; *keleetuu,* two; *salastuu,* three; *arbaa'tuu,* four; *xamestuu,* five; *me'et,* a hundred; *elf,* a thousand.

Proto-Semitic is the hypothetical reconstructed language spoken 5000 B. C. and earlier. Its words are obtained by a comparative study of Hebrew, Syriac (a dialect of which was spoken by Jesus Christ), Phenician, Babylonian, Arabic and Ethiopian. The forms of old Ethiopian, of which we have just given sample words, are found often to coincide with those of Proto-Semitic!

We shall follow these examples with still more interesting titles of the Emperor and common words, which have appeared in the newspapers or which have connection with the present Ethiopian situation, in the modern official Amharic dialect of Ethiopia.

Hhay-leh Seh-lahs-syeh' Me-djem-meh-riah', Haile Selassie I. *Hhay-leh,* the Power or Virtue. *Seh-lahs-syeh',* of the Holy Trinity. *Me-djem-meh-riah',* the First.

Moh-ghah an-beh-sah' za-'em-ne-ged' Yeh-hu'-da, hath prevailed the lion of the tribe of Judah—ancient epithet of the King of Ethiopia. This motto means that Judah, the "lion's whelp" of the Old Testament' has prevailed over the other tribes. It refers to the Emperor's descent from King Solomon, of the tribe of Judah. It has been mistranslated as the "conquering lion of Judah."

Neh-guh-seh neh-gest', King of Kings; that is the Ethiopian way of saying "emperor." So called because the emperor is supposed to have kings under him From *neh-guhs',* king. But the governors of the provinces are called *gehg.*

Zar-'ah Tseh-yohn', Bat-rah Tseh-yohn', the posterity of Zion, the staff of Zion, another ancient epithet of the Ethiopian emperor.

Eh-teh-gyeh', the Empress.

Ih-teh-yoh-peh-yah', Ethiopia — from a Greek word meaning sunburnt or dark-faced, referring to the Ethiopians; *It-yop-yah-wih',* an Ethiopian.

Ghad-wah', Aduwa, where the Ethiopians made a stand in 1896 to protect

their Holy City of Aksum from Italian annexation. *Ghad-wah'* means "the pass."

Ahd-dihs Ah-beh-bah', New Flower. The first word means new, the second means flower. This is the *meh-dih'-nah*, capital. The old capital was *En-toh-toh'*, meaning green place. The spelling "Ababa" is absolutely wrong. The middle vowel is e.

Mah-zer-yah' Tsah-nah', Lake Tsana, at the source of the *Ab-bay'*, Blue Nile. This Ethiopian lake covers 2,980 square kilometers and is the center of the irrigation project for increasing the irrigated lands of Egypt.

Ahm-lahk', God; *Ih-yeh-suhs' Kres-tos'*, Jesus Christ; *Kres-tih-yahn'*, Christian; *Kres-ten-nah'*, Christianity.

Eh-hhih-geh', head of the Ethiopian Church; *Ieh-pis-qoh-pos'*, bishop; *Qyehs*, priest; *Byeht kres-tih-yan'*, church, literally Christian house

Weyn, wine of sacrament; *meh-lahs' goh-ghehz'*, the language of the free, name of the ancient Ethiopian tongue used in the church.

Ih-tah-leh-yah', Italy; *Ih-tah-leh-yan'*, Italian; *En-gliz'*, English.

Leb-yah', Libya, Italian colony west of Egypt one and one half times as large as Egypt; *Gebts*, Egypt; *Qey Bah-hher'*, the Red Sea; *Bah-hher' Rom*, the Mediterranean (literally the Roman) Sea! *Mes-noh'*, the Canal; *Suh-wes'*, Suez; *Port Sayd*, Port Said.

Tor, spear; *yeh-feh-reh-seh-nyoch'*, cavalry, literally horsemen spear; *yeh-medf tor*, artillery, literally cannon spear; *yahz-mach tor*, regiment, literally soldier spear; *yeh-tor mer-keb'*, war vessel, literally boat spear; *bah-ruhd'*, powder; *yeh-bah-ruhd byeht*, powder horn or receptacle, literally powder's house; *yeh-bah-buhr'*, airplane pilot; *ras*, a general, literally a head—meant head in old Hebrew; *weh-tad-der'*, a soldier, fighter; *seyf*, sword; *sam-djah'*, bayonet; *medf*, cannon; *erd*, fortification; *guhd-gwahd'*, the trenches—sounds like "good God!"; *ah-dah-gah' mew-dek'*, an attack; *del*, victory; *neft*, rifle—our word naptha pressed into this use.

Yeh-'irq mah-gah-nay-nyat', the peace meeting (the League of Nations meeting); *as-tah-rah-qih'*, the peacemakers (of the League); *ah-beyt'*, justice.

CHANGING VARNISHES

By Dr. HENRY J. WING

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Four thousand or more years separate the time of the varnishing of the mummy cases in the Metropolitan Museum in New York and the time at which the varnish was put on the butterfly table which you may carefully cherish because it belonged to your great-grandmother. One hundred years may separate the time of finishing of this table and that of your own dining room furniture. However, there may be far greater differences in the last two finishes than between the first two. True, the first varnish was probably applied hot with a paddle, since the art of adding thinners to the varnish was not known, but in general the type of material was much the same as that produced through the ensuing years.

But many of the varnishes and lacquers to-day are only distantly related to those produced in our grandfather's or even our father's time. Furniture lacquers are used which contain no "natural" product. That is, the whole film may be made of products produced synthetically. Others may contain some oils which have simply been treated but which contain new resins in place of the

natural gums which were used in the varnishes of yesterday.

These changes have brought about harder, smoother finishes and ones which resist rubbing, scratching and water or other liquids to a much greater degree than did their predecessors. They also have the advantage that the manufacturer can finish more pieces in a given time, for many of them dry rapidly, and so reduce the cost, which is reflected in the price to the consumer.

Other types of finishes have been undergoing change too. Not many years ago the worth of a paint could be readily shown by indicating that the oil used was entirely linseed oil. Modern study has shown that other oils have a very definite place and, in fact, may give desirable properties which otherwise could not be obtained in the paint, varnish or enamel. Increased speed of drying or harder more water repellent films may be brought about by the proper use of some of the newer types of oils.

"Oils for the lamps of China" may be an important industry, but within the last few years China has been shipping large quantities of two other types of oil to the rest of the world. These oils from the view-point of the paint and varnish maker are of the highest importance. One of them, chinawood oil or tung oil, has been produced for years, but it has been only within perhaps the last twenty-five years that it has assumed an important place in the paint industry. Its use depended upon the discovery of the proper method of treatment in order that it might be used as a paint or varnish vehicle. When this method was once worked out, great improvement in the water resistance of varnishes and of paints and enamels made from them was brought about. Now it has become so important that large areas in Louisiana and other southern states have been set out in tung tree groves. This domestic oil is very slowly coming on the market, the result of careful experimentation as to proper conditions for the growth and cultivation of the trees.

China also exports large quantities of another oil, most of which is obtained from the northern part or from Manchuria. This is obtained from soya beans, the same kind of beans which were so widely recommended in some sections of our Middle West last year, after the drought had broken, for use as a quick-growing forage in order to partly replace the crops which had been destroyed. This oil also was one which only awaited the discovery of proper methods of processing to make it a valuable paint ingredient. Its use has been widely publicized by the producer of one of our popular cars, who has shown that the beans can be grown and the oil extracted successfully in this country. In fact, we now produce more than our requirements. However, this was not accomplished without long and careful investigation of the properties of the oil and the best methods for treating it in order to make it a useful ingredient for paint manufacture.

Paints, varnishes and enamels have all been mentioned. However, the liquid used in each may be quite similar. A clear or unpigmented coating material, if made principally from oils or oils and resins, is a varnish. This same varnish may be used in paints or enamels, although many modern paints contain but little varnish, the vehicle being an oil treated to cause proper drying. The main distinction between a paint and an enamel is that an enamel is glossier than a paint. This glossiness, if the same vehicle is used, is due in part to the fact that the pigment particles in the enamel are much smaller than those in the paint. In general, decreasing the size of the pigment particles increases the glossiness of the finished product.

For years most automobiles were finished with oil type varnish enamels. A few in the lowest price range received a baked black enamel, but for the most

part the speed of motor car production had to be fitted to the drying time of the enamels used. Some improvements were made. New types of driers were introduced into the varnish, which speeded up the finishing process, but the increased speed of drying usually meant a decided decrease in the wearing qualities of the finish on the car.

For many years lacquers were used which depended on the evaporation of solvents for producing the finished film. Nitrocellulose was used as the film-forming material in some of these, but it had the disadvantage that in order to make solutions thin enough to be applied properly, it was possible to use only very little solid nitrocellulose in the lacquer. A freely-flowing lacquer containing much more than 6 per cent. nitrocellulose could not be made. Even this lacquer was the product of long and painstaking research, for it had developed with the making of gun cotton, photographic films and celluloid.

About 1925 an entirely new aspect of the protective coating field was opened up purely on the basis of research. Methods were discovered by which nitrocellulose could be made such that solutions containing as high as 15 per cent. of this solid were more fluid than the old 6 per cent. lacquers.

In the development of these lacquers we find an example of the interdependence between various chemical processes. During the world war the allies, and later our forces, needed large quantities of acetone to make "dope" or lacquer for airplane wings. Chemists in this country quickly adopted for large-scale production a process whereby certain types of bacteria acting on corn mash produced acetone and the little known butyl alcohol, a relative of grain alcohol but having a larger molecule. This process was very successful, so successful, in fact, that enormous tanks of by-product butyl alcohol were soon accumulated. The close of the war still found no extensive use for this material, but ten years later this same process, based on the bacterial action, became again of great importance. Now the two products found their rôles reversed. Butyl alcohol had become the important product and acetone the by-product.

This change of state was due to the rapid development of the nitrocellulose lacquer industry. This new industry used more and more solvents, and one of the most important solvents was made from butyl alcohol. Butyl alcohol and its compounds are still important lacquer solvents, but the rise of the lacquer industry has stimulated research and brought about the development of many others.

This same demand has been reflected in the development of processes for making solvents from the by-products of gasoline manufacture. Here a curious interlocking of processes has appeared. Our modern high compression automobile motors demand a gasoline of low knocking properties. One way of producing this gasoline is to heat heavy petroleum fractions to high temperatures. Under these conditions lighter molecules are formed which in part go to make gasoline. At the same time large quantities of unsaturated gases are produced. Within the last year or two it has been found possible to so treat part of these gases that alcohols and other organic solvents of great importance to the lacquer industry may be produced. Many organic compounds which were laboratory curiosities ten years ago are now made in carload lots. They find their use in the production of finishes for the beautiful motor cars of to-day.

Modern motor cars are for the most part finished in either of two ways. One large manufacturer uses a type of enamel carrying newly invented resins made by treating oils with phthalicanhydride. This latter chemical, a curiosity but a few years ago, is now produced by the carload.

These finishes are dried by low temperature baking and have the advantage that they require but little polishing for their completion. They have the disadvantage that the refinisher finds them more difficult to repair after minor accidents but that problem has now been solved satisfactorily.

Larger numbers of cars are finished with nitrocellulose enamels. The introduction of these finishes resulted in brighter, glossier cars, even in the lowest price field, and in lowering to some extent the cost of the cars. This economy was accomplished by the great decrease in the time required to finish a car. Before 1925 the finest finishes could be produced only by waiting for at least a day between coats. Now the complete finishing operation can be done in less than a day. This means a great economy in time, with the consequent decrease in costs.

Moreover, these lacquer finishes are better than the varnish finishes of former years, for they are harder and so will take a high polish, and they wear better, for they resist scratching and abrasion to a greater extent than the older type of finish.

WHEN THE DUCKS FLY SOUTH

By Dr. W. B. BELL

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When the ducks fly south each year they carry with them the message of the mysterious rhythm of the seasons. Each southward flight in the fall recalls to mind the thought of other flights in the past, and this thought leads to the anticipation of recurring flights in the future.

The power of this phenomenon of migratory birds to give the onlooker a quickened sense of the enduring rhythms of nature is one of those intangible, esthetic benefits that come with the presence of wildlife—invaluable, we know, and yet valued in such a way that none of us can state its worth. It affects not only the hunter to whom the flight of the ducks means the return of his sport—it can thrill also the non-hunter; in fact, every one who can escape to the outdoors with an awareness of the happenings about him.

And, as our civilization becomes more complex, as life in the city becomes more nerve-racking, we shall be seeking the outdoors in increasing numbers—as sportsmen, as hikers, as tourists. We, and those who come after us, will be appreciating more highly than ever the flights of the ducks. It is for this reason that the conservation of our waterfowl is such an important public problem—a problem in the discussion of which a speaker addresses fellow citizens, not any particular group alone, but all who are a part of the civilization in which we live.

When the ducks fly south most of them cross an international boundary. The public problem of their conservation is, therefore, in this country, a concern of the Federal Government. Nearly twenty years ago the United States and Great Britain agreed by treaty to protect the migratory birds in Canada and this country. The act of Congress that gave effect to this treaty directed the Secretary of Agriculture to determine from time to time "when, to what extent, if at all, and by what means" the hunting of these birds might be allowed, and to adopt suitable regulations to govern hunting. The act charged the secretary with "having due regard to the zones of temperature, and to the distribution, abundance, economic value, breeding habits, and times and lines of migratory flight." Congress thus required a scientific basis

for the regulation of wildfowling, and this basis has been continuously provided by the Bureau of Biological Survey. Ever since the beginning of federal protection of this resource, the Survey has been observing the waterfowl conditions on this continent and making recommendations for its conservation

Throughout all the years of these observations there has been one fact that has almost constantly faced the Survey's investigators That fact is this The ducks are decreasing in numbers. This decrease is not a new thing in our day, but we have reached the time when the waterfowl populations can no longer stand continued decrease As far as some species are concerned, we are fast approaching the minimum that can be reached without inevitable extinction.

Thirty-five years ago, in January, 1900, a writer spent a few days on Currituck Sound hunting canvasbacks On one day when there was no shooting he observed the large numbers of birds during freezing weather "Much of the day," he said (and I am quoting), "was spent on top of the club house, studying their inconceivable numbers. All around the horizon except on the landward side —that is to say, for 270 degrees of the circle—birds were seen in countless numbers Turning the glasses slowly along the horizon from northwest to north, east, south, and southwest, there was no moment at which clouds of flying fowl could not be seen in the field of sight." That is the end of that quotation, but a little farther on in his account, the author says (and I am again quoting), "Looking with the glasses over the smooth ice away to the northward, we could see flying over the ice, or resting on it, fowl as far as the eye could reach."

Reports from the same area last year make only a pitiful comparison with this account at the beginning of this century. Yet even in 1900 the writer whom I have already quoted was alarmed over the decrease in the waterfowl. He devoted the last 35 pages of his book to a chapter entitled "The Decrease of Wildfowl." It is more than interesting to note that he attributed the decline to two main causes, and these causes are precisely the same as those that appear to us to-day. He wrote (and I quote), "Two prime causes exist for the diminution of wildfowl These are over-shooting, and the settling up of the country."

To-day we are in a startling situation. Thirty-five years after such a clear warning, the birds continue to decrease—and for the same reasons that were pointed out a generation ago! The forces of conservation move slowly among a people as uninformed and unconcerned as we Americans have been in the past. Yet these forces do move, and it is the recent acceleration of this movement that brings the matter to the attention of this nation-wide radio audience To-day the people of the United States are trying to stop the decrease in waterfowl Through the U S Biological Survey the Federal Government is carrying out a national program of waterfowl restoration. This program is based on the facts gathered by the Survey's scientists.

Two causes for the waterfowl decrease —two aspects of the restoration program. If one cause is the "settling up of the country," one remedy will be restoring to the birds areas that have been unwisely devoted to agriculture And so, the Biological Survey, of the U. S. Department of Agriculture, is establishing refuges—places where the birds may breed or winter in safety In time the Biological Survey hopes to give back to the birds some 3,000,000 acres These areas must be selected, and in most cases they must be developed. To be done right the selection and the development activities must be based on scientific facts. Well-qualified naturalists are thus employed to select areas that are biologically suitable and to recommend improvement measures. This is science service for the refuge program.

The other aspect of the restoration program deals with overshooting as a cause of the decline in our waterfowl populations. Now, the remedy for this would on first glance seem apparent. If shooting is threatening our birds, prohibiting this practice would seem to be the quick and easy method of stopping the decrease. But the question arises. "How shall we stop the overshooting?" One answer is "Make a federal regulation to close the season," but it is an answer that seems to underestimate practical difficulties. More than a million people are vitally concerned with the waterfowl hunting regulations, and when I say vitally concerned with them I mean that they are going to protest vigorously against any restriction that seems unjustified. In a democracy such protests necessarily have an effect on government. That is a very real consideration to administrators of federal regulations. Furthermore, under present conditions, the enforcement of the federal game laws is dependent to a great extent on the cooperation of state agencies and of sportsmen. Thus the whole problem of regulating shooting becomes one essentially of education with an always current need for up-to-date information.

There is another reason for our need for up-to-date information each year. Of the two alternatives—prohibiting hunting or allowing it with severe restrictions—the wiser seems to be the one that is less drastic. Yet if hunting is to be allowed we must be certain that it does not mean a continuance of overshooting. We must be certain that our annual loss from all causes—including hunting—is less than our annual increase from breeding. This policy makes it necessary to keep books on our ducks.

The need for basic data on the status of waterfowl is a need for the services of scientists. These scientists must be competent naturalists whose reports may be used effectively in informing the public of the actual waterfowl conditions In other words, they must provide the factual basis for the educational work in the national conservation program More important still they must provide the data on which the hunting regulations are based.

The Biological Survey's personnel includes such scientists, and they have been conducting the most extensive field studies of waterfowl ever undertaken. As the birds move south in the fall to the swamps of Louisiana, to the lagoons of Texas, to the lakes of Florida, even to tropical Yucatan, the Biological Survey scientists follow them After the hunting season the survey men continue to check up on the waterfowl populations and conditions. The week starting Monday, January 21, 1935, was, for instance, selected for a checkup on the waterfowl population on the winter resting and feeding areas by Biological Survey scientists—the most comprehensive study and carefully planned survey that has ever been undertaken for this purpose. A selected group of about 300 field agents attempted a simultaneous estimate on the concentration areas. The most severe storm of the winter, covering nearly the entire country, set in on the day the inventory was to start. Yet the men assigned to the job did an excellent piece of work; and, while the results obtained were inadequate, the methods and experience gained point to more efficient results in the future. Confronted by snow-blocked highways and suddenly frozen watercourses, the men succeeded in one way or another in getting to a large number of waterfowl concentration areas. One agent was actually marooned for nearly a week on a small island in Chesapeake Bay, where he received emergency food supplies dropped by an airplane, and was finally rescued by a Coast Guard cutter that was able to break through the ice The reports of the agents were assembled by the eight regional directors of the Bio-

logical Survey, who then made corrections to allow for the good duck areas it had been impossible for agents to reach. And after the winter was over—when the birds had again flown north—the Biological Survey naturalists observed the conditions on the breeding grounds

It should be borne in mind constantly that the entire breeding range of all species of migratory waterfowl covers a vast area. Broadly speaking, it includes the entire continental land mass north of the 40th parallel of latitude. This crosses the middle of the United States and forms the northern boundary of Kansas. A considerable number of ducks also nest even south of that line. Obviously, no individual worker or limited group of specialists can cover so vast an area in one season. There are, in fact, not enough biologists in the entire United States and Canada to do the job, even if they were all working on it. It is possible, however, to get good results by the "sampling" method, and that is what the Biological Survey has done

The summer work is made to determine the probable ratio of increase from nesting. It should not be confused with the census or winter inventory. This inventory is made on the southern waters, in mid-winter, when the birds are rafting on the open water. A summer count when the birds are hidden by heavy vegetation has proved too inadequate to be of any value

Five field parties were assigned this year to the Canadian breeding grounds—one in British Columbia; one in southern Alberta and Saskatchewan; and one in northern Alberta and Mackenzie; one in Manitoba and southeastern Saskatchewan; and one in the Maritime provinces of New Brunswick and Nova Scotia. The leaders of all five of these parties had previous experience in the regions assigned to them, and in most cases they operated in the same territories during the season of 1934.

The results of these scientifically conducted investigations indicate that the waterfowl have not yet by any means emerged from the crisis. They do show, however, that conditions are slightly improved over last year, and that the net annual increase required for restoration can be obtained with a short open season with severe restrictions.

Accordingly, the season last fall consisted of only thirty days in each of two zones—in northern states, from October 21 to November 19, and in southern states, from November 20 to December 19. Legal hunting of waterfowl on these days did not start until 7 A. M., and closed at 4 P. M. No live decoys could be used Shooting over baited waters or land was taboo, too, as was also the open water shooting that has been so destructive to diving ducks. Careful studies by the Biological Survey had shown that all these practices make heavy kills far easier for the hunter

When the ducks again fly south, we thus hope to see larger numbers than last fall, and so also the next year after that, and the next, and the next. Our hope is a reasonable one. With the hearty cooperation of conservation agencies, state game departments and local sportsmen; with regulations formed on a scientific basis; and with policies that are formulated with careful regard for their practicability, the program can be realized. It does require cooperation on the part of some who might wish conditions otherwise. It does require the awakened interest of the non-hunting public as well as the sportsmen. But, withal, the prospects are encouraging, and we are working earnestly to accomplish the restoration of the waterfowl—an immensely valuable natural resource. It means money for many, but it means sport, recreation and esthetic delight for countless others also. I thank you for your interest, and I wish for each of you many, many autumns in the future to behold the inspiring spectacle that is in the skies when the ducks fly south

THE WHALE SHARK OFF HAVANA

By Dr. E. W. GUDGER
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I HAVE been pursuing the whale shark for twenty-three years, yet, from the perusal of a vast literature together with the letters of a far-flung correspondence, I have been able to enumerate, as of January 1, 1935, but seventy-six definite records Since then I have recorded a sixth specimen from Acapulco, Mexico—the seventy-seventh known fish. The seventy-eighth fish was recently recorded by C. S. Brimley from a specimen which came ashore at the mouth of the Cape Fear River, N. C, in June, 1934 And now comes the seventy-ninth record of the largest and most strangely marked and colored shark, *Rhineodon typus,* that swims the seas. So the capture of a new specimen and the taking of a good photograph of it are of the order of an event, ichthyologically speaking.

Two other whale sharks have been captured off Havana and have been recorded by Dr. W H Hoffmann and myself. And now to these, I add a third.

The first Havana specimen was taken on November 20, 1927, at Jaimanitas, a fishing village about five miles west of the mouth of Havana Harbor In round numbers this fish was thirty-two feet in length and eighteen in girth. Its body was about six feet in depth and the "small" of the tail was so great that a grown man could barely encircle it with his arms The heart weighed forty-three pounds, the liver 900, and the total weight was estimated at nine tons. In the published record (1928) four figures of the fish were reproduced.

The second Havana whale shark was taken on March 10, 1930, at Cojimar Bay, about five miles east of the mouth of Havana Harbor. This giant was thirty-four feet long and its weight was also estimated at nine tons. Dr. Hoffmann and I put this specimen on record in 1930 but without reproducing the photograph This was remedied in 1931, when we published a third article with all the photographs of both specimens

And now I have the pleasure of putting on record the third Havana *Rhineodon*—captured on April 12, 1934 To preserve symmetry in the geography of these captures, this last fish allowed itself to be taken in the mouth of Havana Harbor, opposite Morro Castle. It was harpooned by Captain Tom Gifford, whom I made known as the captor of a *Rhineodon* off Miami, in January, 1932.

Captain Gifford had charge of a private yacht, with owner and party out fishing for marlin swordfish One of the party was fighting a marlin when the whale shark came swimming fearlessly up toward the stern of the yacht. When almost at the stern, the harpoon was thrown The great shark then turned and sounded. Having a heavy line on the harpoon, the fish was presently brought to the surface, tied to the stern of the yacht and towed into the harbor Here it was swung up on the side of the yacht and dispatched with a rifle (15 shots being required). Like all the other whale sharks for which I have records, this one put up no fight, and in fact did practically nothing but try to swim away

This excellent photograph of this great fish shows it swung up alongside the yacht On its body note the parallel ridges—one dorsal and three lateral (on each side). Note also the vertical bars (in some cases made of confluent spots), and in the rectangles thus formed note the large white or yellow spots This rectangular arrangement of bars and spots has led the Cubans to call our fish *pez dama* (checkerboard fish).

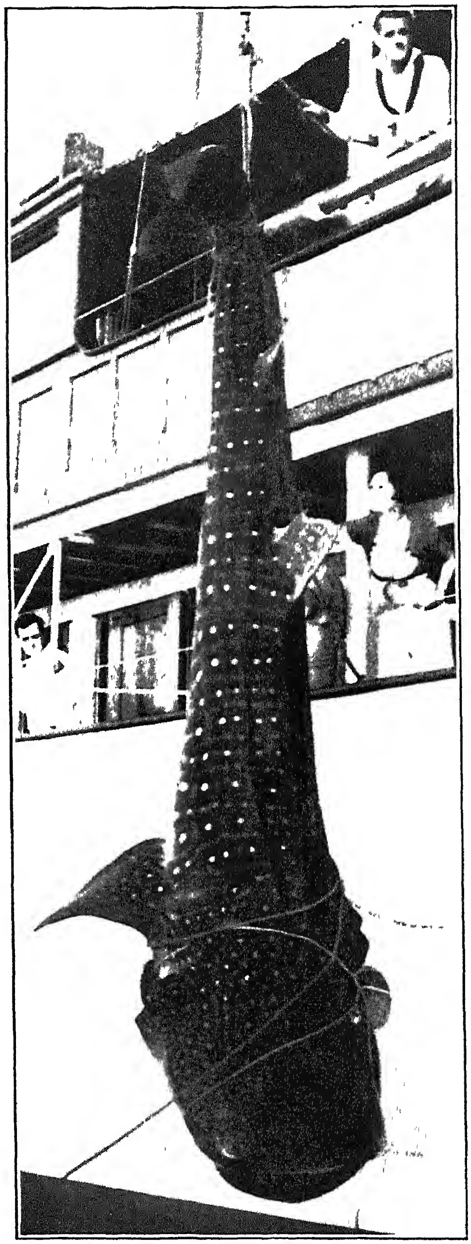
Noteworthy also are the huge gill-slits —exceeded in length only by those of the basking shark of colder waters, which

grows to about the same size—the huge broad head, spotted all over, and the enormous terminal mouth Most sharks have the mouth under the head, hence the fiction that a shark must turn on its back to bite, and none (not even the basking shark) has a mouth so large as *Rhineodon.* With the jaws wide open this fish could take a boy into its mouth cavity.

This specimen was twenty feet, ten inches in length and its weight was estimated at 5,000 pounds. Since whale sharks have been measured up to forty-five feet and estimated up to sixty by scientific men and by whalers used to making such estimates, this one must be reckoned a young and a comparatively small specimen. The relatively small size of this particular fish was a fortunate matter, since it made it possible to swing up the fish alongside the yacht and to make the beautiful photograph shown in the figure

This photograph, showing so clearly the extraordinary markings and coloration of *Rhineodon*, is a great addition to the collection of photographs of this shark in the American Museum—the largest aggregation of such photographs in the world. In this collection there is but one other picture which even rivals this one. For this latest photograph, I am indebted to the courtesy of Mr Al Pflueger, naturalist and taxidermist of Miami, Florida.

This is the eighth whale shark taken in the Straits of Florida. The first record goes back to 1902, when an eighteen-foot specimen came ashore at Ormond Beach, Fla. The record will surely grow, since reports have for a number of years been coming in to me of the whale sharks seen off Havana, and particularly in the waters between Miami and the Bahama Islands These reports are probably true, since the fish is becoming pretty well known—especially to the fishing boat captains at Miami.



NOTE· Persons interested in the history and distribution of the whale shark throughout the warm waters of the world are referred to my article in the Proceedings of the Zoological Society of London for 1934 (1935, pp. 853–893, 2 pls. and 2 maps). This contains a complete bibliography of *Rhineodon* to January 1, 1935.

PROFESSOR FREDERICK JOLIOT AND MME IRENE CURIE JOLIOT

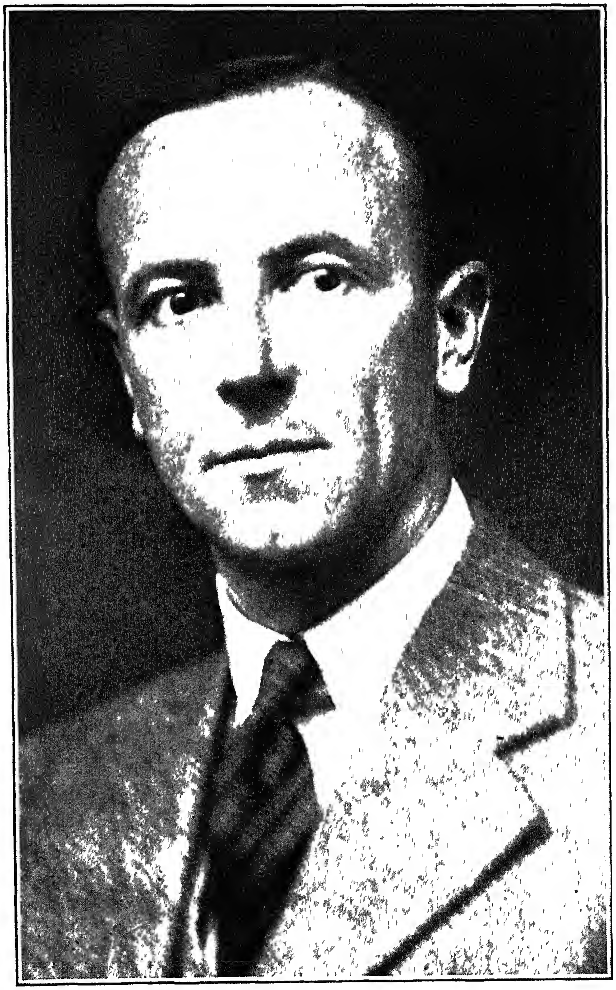
THE PROGRESS OF SCIENCE

AWARD OF THE NOBEL PRIZE IN PHYSICS TO JAMES CHADWICK AND IN CHEMISTRY TO FREDERICK AND IRENE CURIE JOLIOT

So closely linked have been the discoveries of the neutron and of artificial radioactivity that it is fortunate that there are two closely related Nobel prizes, one of which (physics) could be awarded this year to Professor James Chadwick for the exceedingly important discovery of the neutron and the other of which (chemistry) could go to the Joliots for the no less significant discovery of artificial radioactivity.

Never have two Nobel prizes been more richly merited, for the two discoveries together have drawn the veil from the holy of holies of the physical world — the heart, or nucleus, of the atom—and revealed the activities going on therein—activities which have determined and are still determining the fates, not of peoples and kingdoms, but of worlds and galaxies. Through these discoveries we can now begin to see how some of the heavier atoms are being built up under our eyes out of hydrogen Also with their aid we have already produced more than seventy definite cases of the "transmutation of the elements."

Professor James Chadwick has been one of the most able and most fruitful workers in the Cavendish laboratory for fully twenty years and has just this year left that post to accept the professorship of physics in the University of Liverpool. His name has been associated with many important problems in the field of radioactivity and atomic physics. One of the most difficult and most important of these consisted in the accurate determination in 1920 of the charge on the nuclei of several atoms from the scattering of alpha particles by these nuclei. It certainly was a triumph of experimental skill when the charge on the nuclei of the atoms of lead, silver and cop-



PROFESSOR JAMES CHADWICK

per came out of such scattering measurements by Chadwick as 77 4, 46 3 and 29.3 in place of 78, 47 and 29, the whole number values given them in the atomic number series With this kind of a record the world of physics was not surprised by the skill and insight shown in the discovery of the neutron Although Bothe and Becker in Germany and the Joliots in Paris had prepared the way for him, it was Chadwick who marshalled the old evidence for the existence of the neutron, then predicted new results on the assumption of its existence and checked the prediction by unambiguous experimental proof.

It is surely a significant circumstance that the babe who was being conceived and born when radium was being discovered by the joint work of that babe's father and mother should, thirty-eight years later, working in her turn with her own husband, F. Joliot, follow the lead of her parents in making a great discovery in the field of radioactivity Until this work was done every one believed that the phenomenon of radioactivity was completely beyond the control of man, yet here it was produced *artificially*, and since then it has been produced in several different ways and with scores of different working substances What may we not expect from the third generation of Curies which is already on the way?

Also without the preceding work of Bothe and Becker in Germany and that of the two Joliots in Paris, Chadwick could scarcely have been in position to get in Cambridge the proof of the existence of the neutron Big results then have followed from these discoveries which are being honored by this year's Nobel prizes.

ROBERT A MILLIKAN

THE ANNUAL MEETING OF THE AMERICAN ASSOCIATION

How different is the world to-day from what it was when, fifty-seven years ago, the association held its first St. Louis meeting At that time applied science was in its infancy Indeed, all forms of science were in a more or less elementary state, judged by the standards of to-day

Between the time of the first and the present fourth St Louis meetings science has so modified our mode of life and way of living and has provided us with so very many things we now regard as indispensable necessities that it is difficult to imagine ourselves back in those earlier days

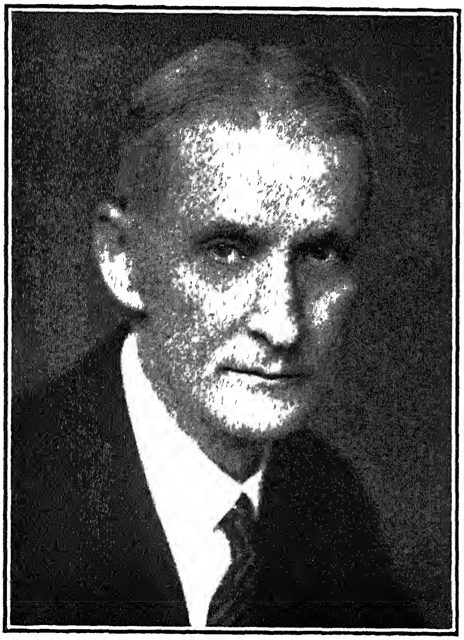
The transformation that has taken place during the past threescore of years has in no small degree been stimulated by the meetings of the association. These annual meetings serve a double purpose.

In the first place, they serve to bring together the scientific workers of the country. Through the presentation of technical addresses and papers and by discussions the latest advances in all lines of science are made generally known The students in all lines of science are able to exchange ideas and information, and by so doing each is able to obtain a clearer insight into what is being done in his or her field of special interest—astronomy, zoology, physics, chemistry, the social sciences or whatever it may be—than would be possible merely by reading printed memoirs

And besides all this the research workers, most of whom are connected with universities, colleges and schools or museums or other institutions throughout the country, are able to meet each other and to form lasting friendships which in later years serve to stimulate and to increase the interest in the search for scientific truth For the younger men especially this is a very great advantage. They are able at these meetings to meet the older men who are the recognized leaders in their special lines and from this personal contact to gain increased

DR. T. H HILDEBRANDT
PROFESSOR OF MATHEMATICS, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION OF MATHEMATICS.

DR MOSES GOMBERG
PROFESSOR OF CHEMISTRY, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION OF CHEMISTRY.



DR HERBERT R. MORGAN
ASTRONOMER, UNITED STATES NAVAL OBSERVATORY; CHAIRMAN OF THE SECTION OF ASTRONOMY.

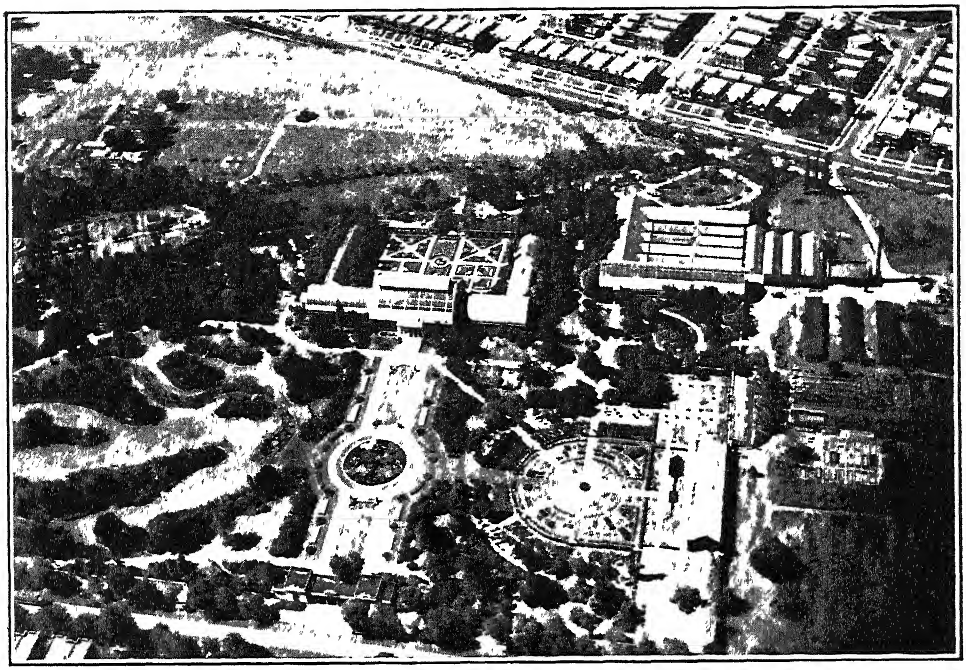
DR WALTER E McCOURT
PROFESSOR OF GEOLOGY, WASHINGTON UNIVERSITY; CHAIRMAN OF THE SECTION OF GEOLOGY AND GEOGRAPHY.

DR. OSCAR RIDDLE
STATION FOR EXPERIMENTAL EVOLUTION, CARNEGIE INSTITUTION, CHAIRMAN OF THE SECTION OF THE ZOOLOGICAL SCIENCES.

NELS C. NELSON
CURATOR OF PREHISTORIC ARCHEOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; CHAIRMAN FOR ANTHROPOLOGY.

THE LATE DR. JOSEPH PETERSON
AT THE TIME OF HIS DEATH PROFESSOR OF PSYCHOLOGY, GEORGE PEABODY COLLEGE FOR TEACHERS; CHAIRMAN FOR PSYCHOLOGY.

SHELBY M. HARRISON
GENERAL DIRECTOR OF THE RUSSELL SAGE FOUNDATION; CHAIRMAN FOR SOCIAL AND ECONOMIC SCIENCES.



AERIAL VIEW OF THE MISSOURI BOTANICAL GARDEN

confidence in the value of their own work and, more important still, to learn how their special work fits into the structure of science as a whole, and the relation of science as a whole to the broader phases of human activities and of human thought.

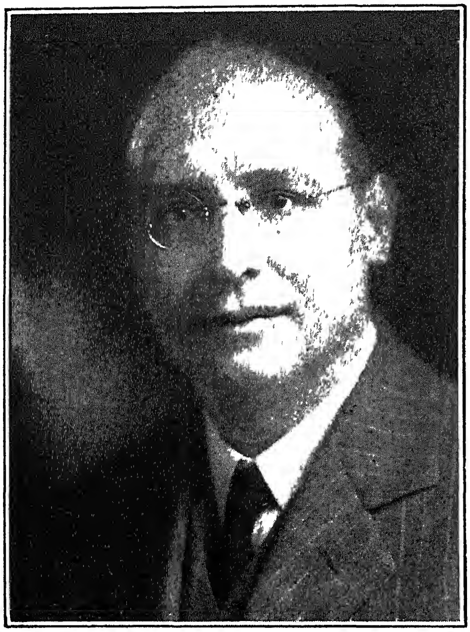
This aspect of the meetings is of interest chiefly to the members of the association and their guests, though every one who is interested in any of the various branches of science may attend the meetings.

In the second place, the association realizes its responsibilities to the general public. The ultimate aim of all scientific work is the betterment of human welfare, both in its material and in its non-material aspects. Every established scientific fact has a definite bearing on some phase or other of human activity or of human thought. Not so very long ago many of the principles involved in the operation of the radio were regarded as merely curious phenomena and were unknown except in the laboratories of the physicists The curious isolated facts of one decade may in the next become correlated with other facts into basic principles. In science no one can foretell what is going to happen.

But science can not advance unless it has the support of the people as a whole. Popular support is based upon popular interest, which leads to confidence in the workers and in the work produced.

So in connection with the meetings of the association there are given a number of popular talks which treat of scientific subjects in a broad way and in language intelligible to all. These talks show how the data upon which scientific generalizations are based are accumulated and correlated, and by this correlation are made useful.

Such talks deal with the exploration of unknown or of little known portions of the earth's surface, with the exploration of unknown or little known portions of, or objects in, the skies, or with the ex-



DR GEORGE SARTON

LECTURER ON THE HISTORY OF SCIENCE, HARVARD UNIVERSITY, CHAIRMAN FOR THE HISTORICAL AND PHILOLOGICAL SCIENCES.

DR. HARVEY N. DAVIS

PRESIDENT OF THE STEVENS INSTITUTE OF TECHNOLOGY; CHAIRMAN OF THE SECTION OF ENGINEERING.

DR. STANHOPE BAYNE-JONES

PROFESSOR OF BACTERIOLOGY, SCHOOL OF MEDICINE, YALE UNIVERSITY; CHAIRMAN OF THE SECTION OF THE MEDICAL SCIENCES.

DR. H. K. HAYES

PROFESSOR OF AGRONOMY AND PLANT GENETICS, UNIVERSITY OF MINNESOTA; CHAIRMAN FOR AGRICULTURE.

ploration of the borderlands of physics, chemistry or biology They also deal with the more concrete problem of just how science affects us in our daily lives. In these talks the broader aspects of the technical advances such as those described in the more formal papers are presented in simple language that can be understood by every one

Talks and addresses, however, are not the only means by which the advances of science are brought to the attention of the members and the guests at the association's meetings For some years now the annual science exhibition has been an increasingly important function of these gatherings. In this exhibition may be seen the latest and most improved apparatus used in scientific research in very many different lines Demonstrations vividly portray many of the more recent truths discovered, and the application of new scientific methods in the arts, industries and commerce. And besides all this, there are shown the latest and most authoritative books on almost every scientific subject.

The meetings of the association year by year form a continuing picture of the onward march of science, showing what has been accomplished, and at the same time pointing the way to further and more efficient exploration of the infinite expanse of the still unknown.

The background of this picture, the increasing interest in, and support of, science in this country, is furnished by the progressive increase in the numbers of the association's members. At the time of the first St Louis meeting, in August, 1878, there were 618 members. By the time of the second St. Louis meeting, in December, 1903, to January, 1904, the number had risen to 4,127. The membership at the time of the third St. Louis meeting, in December, 1919, to January, 1920, had risen to about 11,000. At the present time it is about 18,000

DR. F. B. KNIGHT
PROFESSOR OF PSYCHOLOGY, STATE UNIVERSITY OF IOWA, CHAIRMAN OF THE SECTION OF EDUCATION

The growth of science and the scientific spirit in this country has been as steady as it has been phenomenal. In view of the past we have every reason to be confident of the future

AUSTIN H. CLARK

EXPLORING THE STRATOSPHERE

ON Armistice Day, 1935, Captain A. W Stevens and Captain O A. Anderson took their great stratosphere balloon with its load of scientific apparatus to the record-breaking height of 72,395 feet, and then descended safely to a gentle landing near White Lake, S. Dak. Thus, the third stratosphere expedition under the joint sponsorship of the National Geographic Society and the Army Air Corps was brought to a most successful conclusion.

During the first stratosphere flight in July, 1934, Kepner, Stevens and Ander-

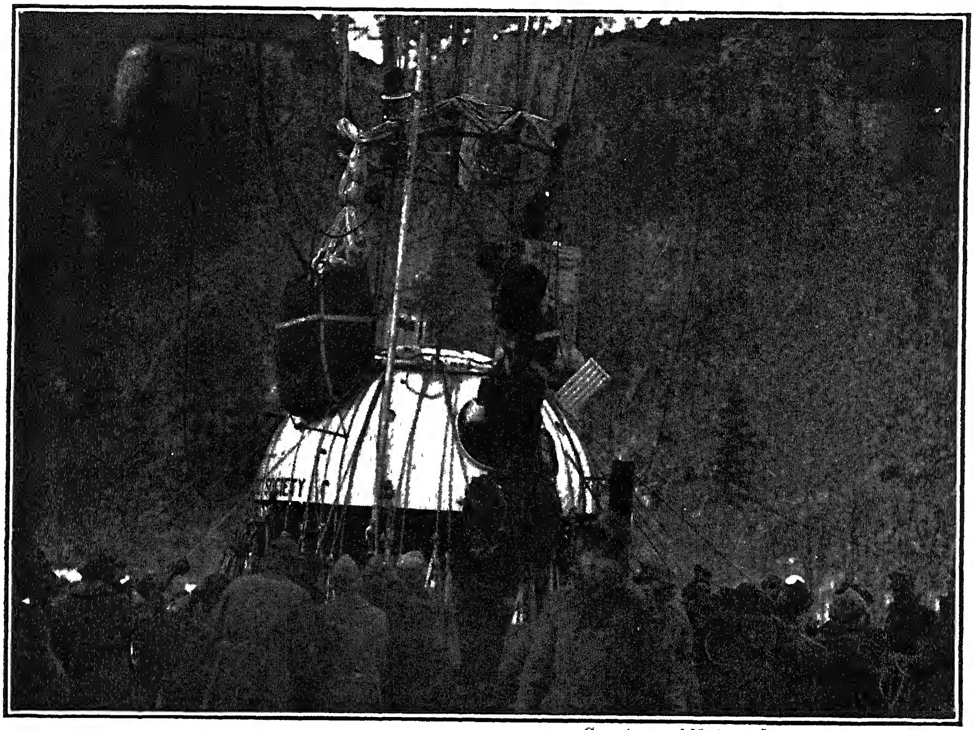
son reached an altitude of about 60,600 feet when rips or tears were discovered in the bottom of the balloon, and an immediate descent was decided upon. These tears increased in size as the balloon came down, until finally the whole bottom of the bag tore away, so that the officers could look directly up into the great balloon. It thus became in effect a parachute, with the upper part filled with hydrogen gas. As the descent continued, the hydrogen became mixed with air. Through friction or some other unknown cause a spark occurred, igniting this explosive mixture, and the top of the balloon was blown to fragments. At this time the balloon was little more than half a mile above the ground, and the gondola, now without any support whatever, fell like a plummet. In the twenty seconds intervening between the explosion and the crash of the gondola in a Nebraska corn-field, Major Kepner and Captains Stevens and Anderson took to their parachutes and landed safely near the wreck of the balloon.

The examination of the fabric of the balloon after the accident showed that the tears in the bottom of the balloon resulted from the adhesion of the balloon fabric, the lower part of which had been folded back into the main body of the balloon to facilitate handling.

Undaunted by the accident to the *Explorer I,* Captains Stevens and Anderson and the sponsors for the flight undertook immediately the development of plans for a second expedition during 1935. To avoid the possibility of another explosion it was decided to use helium in place of hydrogen. Since helium is less buoyant than hydrogen, this necessitated building a larger balloon in order to attain the desired height of over 70,000 feet. The volume of the new balloon, the *Explorer II,* was accordingly increased to 3,700,000 cubic feet. The fabric was treated and the balloon folded in such a way as to eliminate dangerous adhesions. The diameter of the gondola was increased to 9 feet, thus providing more room for the equipment, and the manholes were made larger and easier to get out of in case of an emergency.

In May, 1935, the Stratocamp was again established in the bowl in the Black Hills near Rapid City, S. Dak. After weeks spent in adjusting and testing the instruments and equipment the long looked-for word was given on July 10 that the weather conditions were ideal for a flight on the following day. The inflation went off with clock-like precision, but while the gondola was being attached to the great balloon towering three hundred feet above it, there was a roar of escaping gas and the fabric of the great balloon fell in a tumbled heap over the gondola. The balloon had split across its top!

It was vitally important to determine the cause of this second failure. A searching examination of the top of the balloon showed unmistakably that the rip had started near the tip of the rip panel and had then spread throughout the top of the balloon. The rip panel is a large triangular piece of balloon fabric with reinforced edges and is used to deflate the balloon quickly when it has been brought back to the ground, the idea being to confine the tear to the edges of the rip panel and thus prevent the destruction of the whole top. This construction had been used successfully in other (smaller) stratosphere balloons. After the accident, however, it was suspected that this rip panel, designed primarily to protect the balloon, was in fact the cause of its destruction. Subsequent experiments carried out at the plant of the Goodyear Zeppelin Corporation with a huge model representing the top of the balloon showed this to be true. The reinforcing tapes of the rip panel prevented the balloon from stretching uniformly and the stresses in the fabric near the tip of the panel were found to be far greater than in other parts of the top.



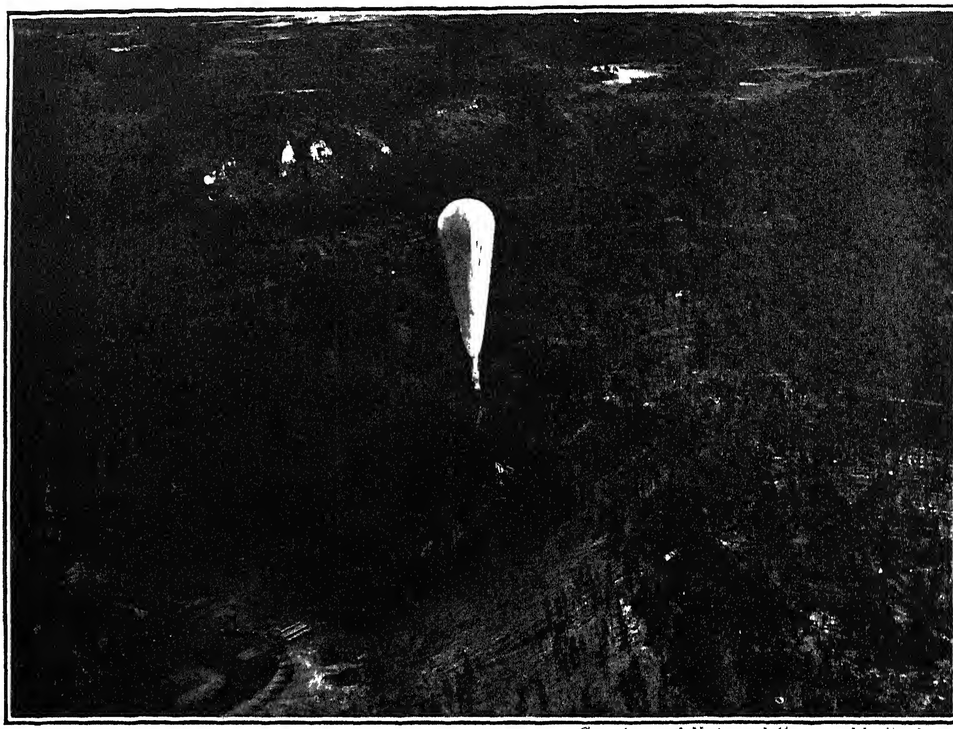
—Courtesy of National Geographic Society—
Army Air Corps Stratosphere Flight

READY FOR THE TAKE-OFF

CAPTAIN ANDERSON IS STANDING WITH ONE FOOT ON THE COIL OF DRAG-ROPE THE LARGE BLACK BAG AT HIS LEFT CONTAINS THE 80-FOOT EMERGENCY PARACHUTE FOR THE GONDOLA. BEHIND HIM IS THE BASKET CONTAINING THE LARGE SPECTROGRAPH THE GROUND CREW IS HOLDING THE BALLOON DOWN.

The cause of the failure had now been definitely determined The solution was to eliminate the rip panel altogether and to use instead a long wire which would cut through the top of the balloon when the rope to which it was attached was pulled. Still determined, the National Geographic Society and the Army Air Corps decided upon a third expedition. The Goodyear Zeppelin Corporation generously volunteered to put a brand new top in the balloon without any cost whatever to the expedition Late in September the camp was again established in the Stratobowl. It was hoped that a flight might be made early in October, but the necessary weather conditions—still air over the bowl for the take-off, cloudless skies to the east and south for 300 miles and low winds at the time of landing—did not develop until some weeks later. For the scientists and soldiers living in tents the undertaking began to assume the character of an Arctic expedition. Temperatures below zero were encountered, but the morale of the camp was unshaken, and on November 10 the looked-for day arrived.

Even this expedition was not to be without its tense moments In introducing the helium gas into a rubberized fabric stiff with cold a pocket of gas at high pressure inadvertently formed in the lower part of the fabric and before the gas could be shut off another tear occurred. When the balloon had risen



—Courtesy of National Geographic Society Army Air Corps Stratosphere Flight

OFF FOR THE STRATOSPHERE

THE GREAT BALLOON SOARS SILENTLY OVER THE RIM OF THE BOWL THE FLOOR OF THE BOWL, WITH ITS RING OF LIGHTS, CAN BE SEEN IN THE FOREGROUND AT THE LEFT.

sufficiently to disclose the damage a tear seventeen feet long was found. In a canvas shelter supported on the backs of soldiers this tear was closed with a patch —closed so skilfully and successfully that after the flight not a trace of slippage could be found.

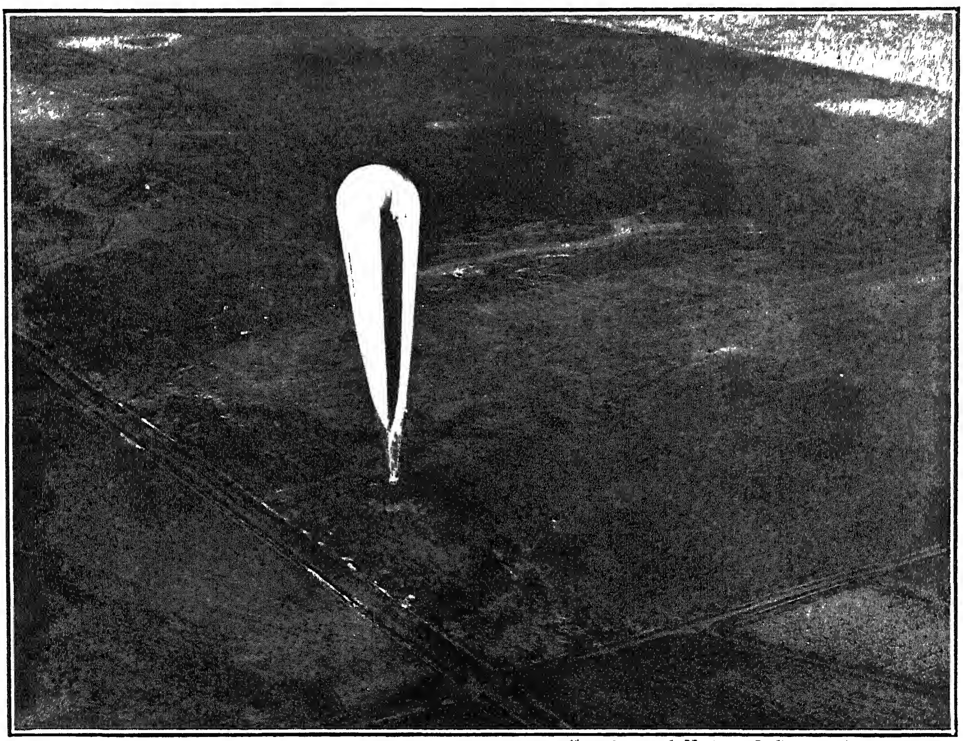
Except for this delay the preparations for the take-off moved forward according to schedule But a precious hour had been lost, and at seven o'clock in the morning, when Captain Anderson gave the word, "Let go," a wind was already blowing across the top of the bowl. Here a second exciting moment occurred. The great balloon had cleared the top of the rim by 150 feet when suddenly it struck a down-draft of air which checked its flight and forced it downward toward the startled spectators below. Their consternation increased when Captain Anderson quickly released 750 pounds of ballast above them in the form of streams of fine lead shot. This loss in weight effectively stopped the descent of the balloon and started it again on its upward flight.

At 17,000 feet the manholes were closed and the gondola made airtight. The balloon then rose steadily until it reached a height of about 65,000 feet. At this altitude the helium had expanded until it completely filled the bag and was escaping through the appendices below. The great balloon had now for the first time taken on its truly spherical form. To go higher it was necessary to lighten the load, and ballast was then gradually discharged until there remained only the amount necessary for use in making a

safe descent and landing. By this time the balloon had reached a height of over 72,000 feet, where it remained an hour and a half for observations.

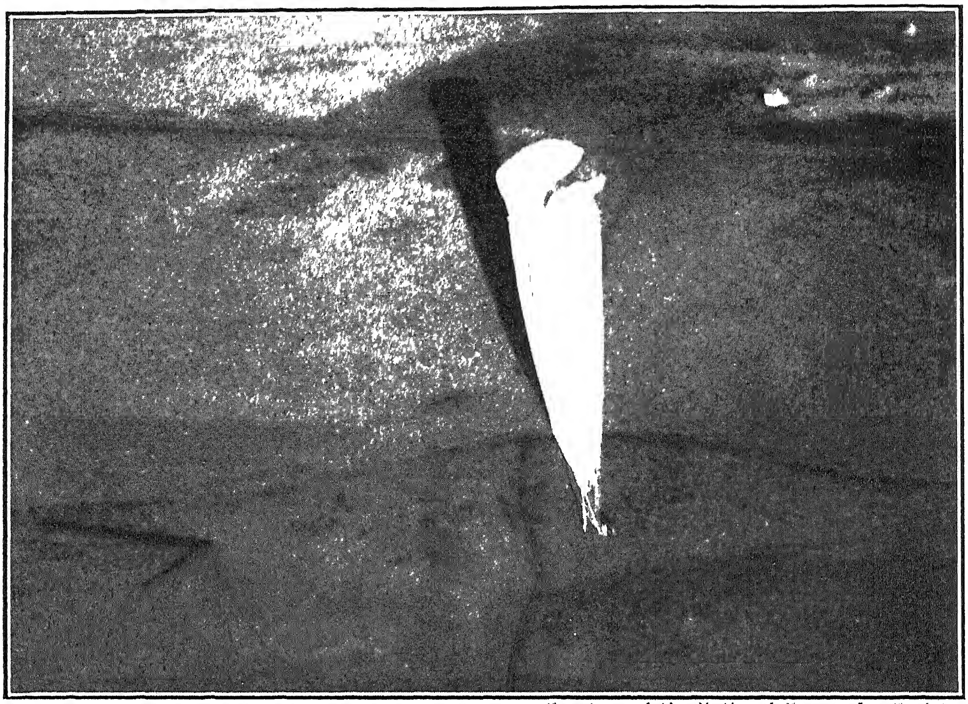
Most of the instruments carried were of the self-recording type. They included two spectrographs for studying the ozone content of the air; an elaborate apparatus for counting the number of cosmic rays coming in from various directions; an instrument for measuring the bursts of radiation produced by cosmic rays; an apparatus for recording the changes in the electrical conductivity of the air from the ground up to the maximum altitude; evacuated flasks for taking samples of air from the stratosphere, equipment for measuring the brightness of the sun, the sky and the earth; a recording electrical thermometer for measuring the temperature of the air; barographs for measuring the air pressure; and a vertical camera taking pictures of the earth below the balloon at uniform intervals of time, which served not only to determine the drift of the balloon at various altitudes but provided an independent check upon the altitude itself. All these instruments appear to have worked satisfactorily, but the results of the investigations will not be known until the records have been carefully studied, which in some cases may require several months.

One part of the program at the top of the flight could not be carried out as planned The gondola had been provided with a long arm with a motor-driven propeller at its end in order that the balloon might be slowly turned about a vertical axis so that the instruments in the gondola could look out at the sky in any desired direction. At the maximum altitude reached by the *Explorer I* in



—*Courtesy of National Geographic Society—Army Air Corps Stratosphere Flight*

THE *EXPLORER II* FLOATS SLOWLY DOWN TO A PERFECT LANDING



—*Courtesy of the National Geographic Society-Army Air Corps Stratosphere Expedition.*

THE FLIGHT IS OVER.

CAPTAIN ANDERSON HAS JUST PULLED THE RIP CORD AND A GREAT RENT APPEARS IN THE TOP OF THE BALLOON THROUGH WHICH THE HELIUM IS ESCAPING.

1934 (61,000 feet) this propeller fan turned the balloon readily. At 72,000 feet, however, Captain Stevens found that in the rarefied air the propeller had so little to push against that the balloon remained practically motionless even when the propeller was rotating at 5,000 revolutions per minute.

The descent was uneventful and Captain Anderson brought the gondola gently to rest in an open field near White Lake, S. Dak., after a flight of about eight hours. None of the instruments or equipment was injured in any way save for the great tear across the top of the bag, which was made in deflating the balloon after landing. Even this could have been avoided had the spectators been willing to catch hold of the drag rope and anchor the balloon, as Captain Anderson implored them to do, in which case the helium could have been released gradually through the valves in the top of the balloon. But either through fear or misunderstanding the spectators left the drag rope severely alone.

LYMAN J BRIGGS

DIRECTOR, NATIONAL BUREAU OF STANDARDS; CHAIRMAN, ADVISORY COMMITTEE, NATIONAL GEOGRAPHIC SOCIETY—ARMY AIR CORPS STRATOSPHERE EXPEDITION

THE SCIENTIFIC MONTHLY

FEBRUARY, 1936

A GENETICIST STUDIES LEUKEMIA

By Dr. E. C. MacDOWELL

DEPARTMENT OF GENETICS, CARNEGIE INSTITUTION OF WASHINGTON

One of the happiest of human experiences is to make a desirable plan and then be able to carry it out. Such has been my experience during the last seven years in studying leukemia And this is true in spite of the fact that this study places leukemia among the most dreaded of all diseases. For the belief has been sustained throughout that this work was leading towards a better understanding of normal life processes as well as of a disease. The opportunity for such a rich experience depended upon the discovery of leukemia in one of the purebred strains of mice in our colony, and upon the greatly appreciated support of Columbia University and Carnegie Institution of Washington, backed by the Carnegie Corporation.

In the technical publications that record these results, broad interpretations are lacking. For interpretations belong to the alluring region just beyond the borders of demonstrable fact. Yet it is this region of interpretation that often gives unity and significance to the separate bits of knowledge; here the investigator spends much of his time; into this region his course must be charted; here lies his keenest interest. With the hope that that which most interests the investigator may interest the reader, I shall deliberately emphasize interpretation. But it must be clearly understood that interpretations are not conclusions, but rather beacons lighting the way.

Leukemia as a Failure in Growth Control

Growth, as one of the primary characteristics of living matter, has been studied from many points of view Usually interest is centered on the progressive phase, but the control or termination of growth may have great significance.

What stops growth? Insufficient food stops a baby's growth; a defective endocrine gland may produce a dwarf; and a certain set of genes may normally stop growth of a mammal before it is larger than your thumb, while another set of genes permits growth to continue until the size of an elephant is reached. But these results consider the individual as though it were homogeneous, as though a sack being filled with grain; they give no understanding of the mechanism that controls the growth of each kind of tissue in forming the harmonious whole, with enough and not too much bone and muscle and connective tissue and skin. It is to this phase of growth that my question especially applies. What stops growth of a given tissue?

As long as the differential control of tissue growth operates successfully, it may seem axiomatic, but failures in the operation of this mechanism immediately raise the question of its nature and at the same time offer a possible approach to its study. For normal processes can frequently be analyzed by their abnormal deviations. Failures in the normal con-

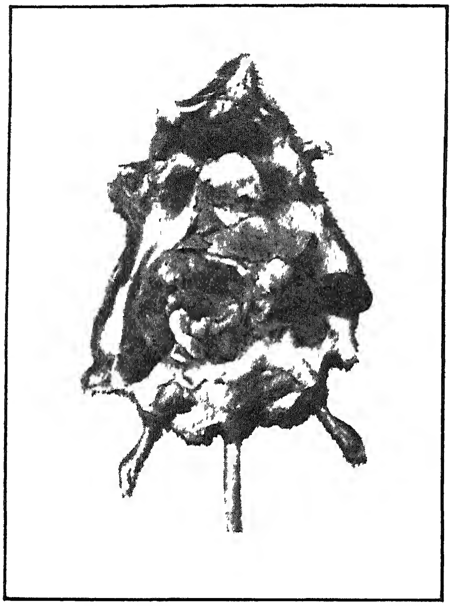


FIG. 1. DISSECTION OF LEUKEMIC MOUSE

SHOWING ENLARGEMENT OF CERVICAL, AXILLARY, INGUINAL, MESENTERIC, POPLITEAL AND LUMBAR LYMPH NODES; GREATLY ENLARGED SPLEEN TURNED OUTWARDS, RIBS ENTIRELY REMOVED, SHOWING TUMOROUS ENLARGEMENT OF THYMUS SURROUNDING HEART, WHICH IS NEARLY CONCEALED

trol of tissue growth lead to tumors A part of some tissue escapes from its normal control and grows wildly without relation to the requirements of the individual; the useless masses of this tissue interfere with normal functions and often interrupt some vital process and cause death. All kinds of tissue may show tumorous growth and many kinds of tumors are named according to the tissue and point of origin.

Some normal tissues, instead of forming compact masses or sheets, consist of independent cells that migrate from place to place Among such tissues are the various types of white blood cells. To recognize tumorous growth of such cells is not easy, for, besides their freedom of migration, their normal functions involve great variations in their numbers However, certain white cells sometimes increase beyond all purpose; they multiply at a terrific rate wherever they are and permeate any or all other tissues of the body. From the enormous numbers of white cells in the blood, the name leukemia was given. *Leukemia* means white blood, as *anemia* means without blood. As used herein, the term leukemia applies to a group of conditions resulting from the wild growth of these white blood cells Pathologists have recognized a certain similarity between leukemia and the conditions resulting from the wild growth of other tissues, but the nature of this disease remained in doubt until experimental studies with mice gave conclusive evidence that it belongs to the class of tumors

Leukemia in Man and Mouse

Mouse leukemia shows the very closest likeness to human leukemia This is true of general characteristics, of variations in manifestation, as well as of the most detailed microscopic features. Indeed microscopic preparations from man and mouse are virtually indistinguishable. Leukemic cells may be distributed in the body with special concentrations in lymph nodes, in spleen, in blood, as well as in kidneys, liver, etc. Again they may be absent from the blood, or they may show very irregular distribution and hugely increase the size of some individual organ or gland Under these circumstances the final picture of this disease is necessarily different in different cases; but in both man and mouse it is fatal (see Figs. 1–4). Reports of cures are usually due to erroneous diagnosis, temporary remission or to an incompleted chronic history. Surgery is futile; radiation, while destroying large numbers of the leukemic cells and sometimes relieving symptoms, does not destroy all the cells.

Incidence

Newspapers are making the term leukemia increasingly familiar. But it is

still one of the rarer human diseases. Its sporadic occurrence does not suggest a strong genetic control A similar sporadic occurrence is generally characteristic of mice. But in 1928 it was discovered that a very large proportion of the mice in one of our highly purified strains developed leukemia. Since this was not the case with other strains raised alongside and under the same conditions, it became obvious that the genetic constitution of this strain was responsible for the high incidence of leukemia. The absence of a similar concentration of cases in any human pedigree does not indicate an important difference in the causation of leukemia; this lack of concentration is probably due to the outbreeding characteristic of human matings in contrast to the extreme inbreeding of these mice. Outbreeding leads to the continued dispersal of any given set of genes, while inbreeding holds them together.

Intrinsic *vs* Extrinsic Influences

But even with the genetic constitution held as uniform as possible in mice, all animals in the leukemic strain did not develop leukemia. In a random sample of over 700 mice, about 10 per cent. failed to show leukemia Although we had strong reason to believe that these negative mice were genetically the same as the ones that developed leukemia, this was checked by breeding tests which showed that leukemia was as frequent in the offspring of these negative parents as in the offspring of leukemic parents. The 10 per cent. that escaped leukemia would have to thank some rare variation in non-genetic influences. These variations in extrinsic influences must be very subtle, for they may cause differences between litter mates living in the same box.

This interplay of intrinsic and extrinsic influences introduces the prin-

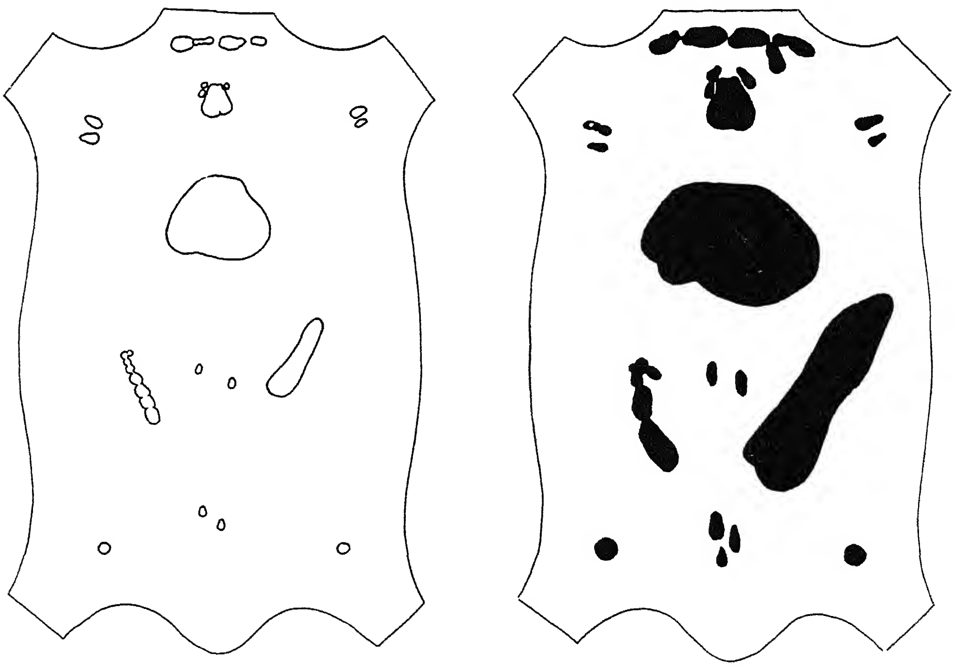


FIG. 2. OUTLINES OF NORMAL ORGANS COMPARED WITH A CASE OF LEUKEMIA WITH MODERATE ENLARGEMENT OF LYMPH NODES AND THYMUS, BUT WITH VERY LARGE LIVER AND SPLEEN.

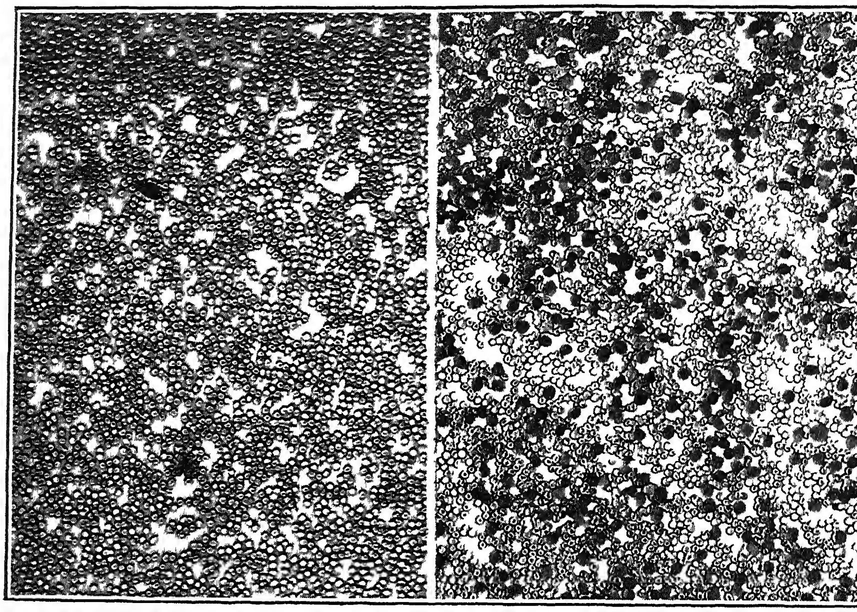


FIG 3. BLOOD SMEARS OF NORMAL AND LEUKEMIC MICE
SMALL CELLS ARE RED CORPUSCLES, LARGE CELLS ARE WHITE CELLS MADE DARK BY WRIGHT'S STAIN.

cipal theme of this composition—a theme running through a vast array of problems; it leads to knowledge upon which practical procedure depends. How far is our modification of extrinsic conditions helpful and how far useless?

With a natural fondness for classification, we have called some traits genetic and other traits non-genetic. This served well enough in the early days of genetics when such strikingly genetic traits as hair color were studied and so-called non-genetic traits were not studied. But when the whole range of traits was surveyed, it became evident that in reality genetic and non-genetic influences co-operate in the production of every trait; sometimes genetic influences are strong and variations in extrinsic factors relatively weak; sometimes genetic influences are weak and extrinsic factors relatively strong. With these extreme conditions in mind, traits have been called genetic and non-genetic. But probably the majority of traits result from some intermediate balance between genetic and non-genetic influences; in these cases the old classification has no meaning. We can say that all traits are genetic; they differ in the degree of their dependence upon extrinsic influences.

In one strain of mice the genetic factors leading to leukemia are so strong that most of the conditions encountered permit its development, but certain rare variations in extrinsic conditions prevent its development. If we could discover what these rare conditions were and could supply them for all the mice, no case of leukemia would appear And yet, in some minds there seems to persist an idea that the discovery of genetic control places a trait beyond reach of extrinsic influence! From the present point of view it would be necessary to study every case before concluding that modification by extrinsic factors was ineffective.

In the same colony as the leukemic strain, another strain of mice has been

inbred over the same period of time. This strain is called non-leukemic, but this is a misnomer, for sporadic cases of leukemia have occurred—less than 2 per cent. Such cases would formerly be called non-genetic, but more correctly we should say that the genetic constitution of this strain leads to leukemia only under certain very rare combinations of extrinsic influences.

Hybridization

In an attempt to study the genetic differences between these two strains, fathers from the leukemic strain were cross-bred to mothers from the non-leukemic strain. The offspring from such a cross are hybrid; they carry half the total heredity from each strain, but they are all genetically alike. However, only about 45 per cent. of them showed leukemia; that is, the reduction of the total inheritance from the leukemic strain by one half has reduced the incidence of leukemia by about one half But there was no intermediacy in the leukemic condition when it did appear. Since the non-leukemic mice have the same genetic constitution as the leukemic, the outcome for each mouse must be decided by extrinsic variables. The reduction in genetic factors has increased the importance of extrinsic factors, since now only about half of the situations encountered favor the development of this disease. The weaker the genetic control the more specialized become the non-genetic requirements.

Here, then, are three groups of mice with three different degrees of leukemic inheritance; within each group there is genetic uniformity, but the relative power of extrinsic influences upon the incidence of leukemia differs for each group (see Fig. 5).

As long as the rôle of extrinsic factors changes with the genetic constitution, the frequency of cases in a second hybrid generation or back-cross can not indicate the number of differential genes.

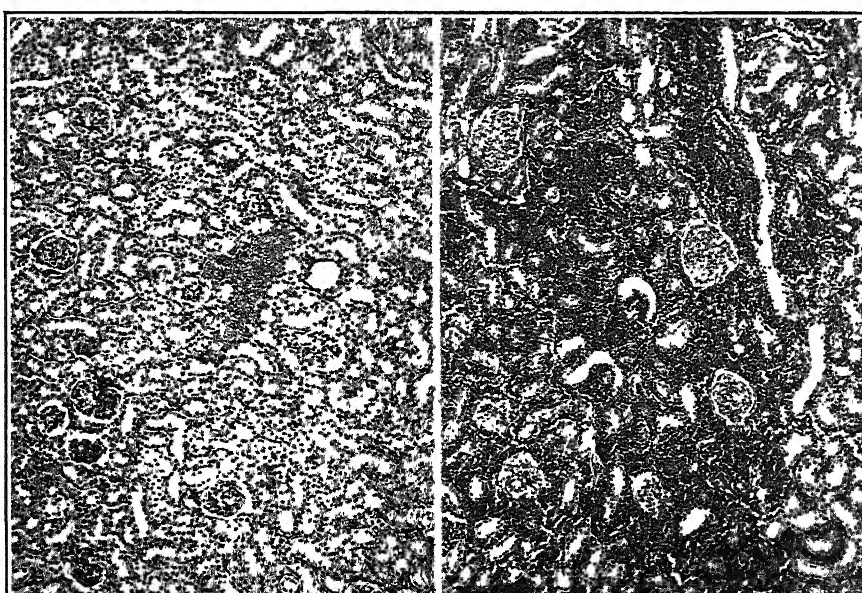


FIG 4 NORMAL KIDNEY STRUCTURE
IN COMPARISON WITH LEUKEMIC KIDNEY IN WHICH THE WILD GROWTH OF LEUKEMIC CELLS HAS FORCED APART THE KIDNEY TUBULES.

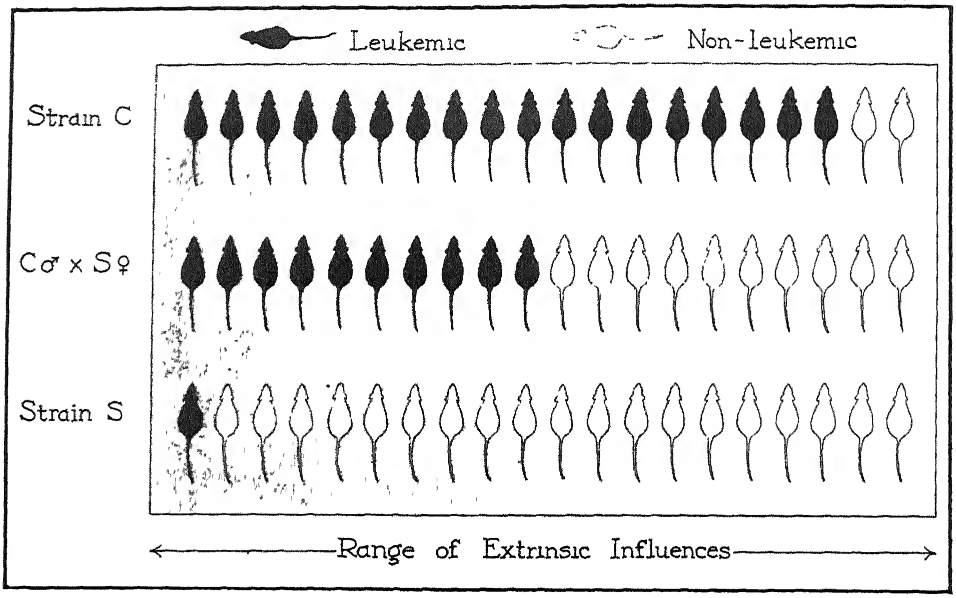


FIG. 5. DIAGRAM; EFFECTIVENESS OF EXTRINSIC INFLUENCES CHANGES WITH GENETIC CONSTITUTION

MICE WITHIN EACH ROW ARE GENETICALLY ALIKE SHADED BACKGROUND REPRESENTS GRADED SERIES OF EXTRINSIC INFLUENCES.

To determine this, the classification of these individuals by complete breeding tests is necessary. Although at present uninterpretable in terms of genes, it may be noted that the back-cross of hybrid males to females of the non-leukemic strain reduces the incidence of leukemia about one fourth that in the leukemic strain, which again corresponds to the proportion of total heredity from the leukemic strain in this generation as a whole.

Genetic and Genic

Genetics has dealt largely with genes, and the evidence in animals of hereditary transmission by any other means has been so conspicuously absent that the term *genetic,* which refers to heredity, is identical in some minds with *genic,* which refers specifically to genes. But in the cases of leukemia, mammary tumors and longevity, evidence has recently appeared that indicates the existence of some other genetic mechanism than genes carried in chromosomes. This evidence is given by differences in results of an out-cross according as the mother or father transmits the trait. In the out-crosses we have been discussing, leukemia has been transmitted in every case by the father. If now the reciprocal crosses are made, with leukemia transmitted through the mother, the incidence of leukemia in both sons and daughters in every case is markedly higher. Sex-linked inheritance is not involved, since sex-linkage does not give the same results for sons from reciprocal matings as for daughters. Now it happens that the non-leukemic strain transmitted a tendency towards the development of mammary tumors as well as greater longevity than the leukemic strain; and these traits also were more strikingly expressed in both first generation hybrids

and back-cross when transmitted through mothers. Murray and Little have reported the same result for mammary tumors

The influence of tumors upon length of life and the influence of length of life upon the incidence of tumors have been studied by several investigators, and it seems clear that longevity can not bear any uniform relation to all tumor incidence. Thus leukemia and shorter life are associated in one strain and mammary tumors and longer life in the other. However, there is serious doubt of these correlations having any causal significance. For instance, leukemic offspring from reciprocal crosses show as much difference in length of life as do the non-leukemic offspring; and comparing the different generations, the correlation fails (see Fig. 6).

From our study of spontaneous leukemia four points stand out:

(1) That genetic and non-genetic influences are active.
(2) That the control exerted by non-genetic factors varies as the genetic constitution varies.
(3) That the incidence of leukemia is correlated with the proportion of heredity from the leukemic strain transmitted through fathers.
(4) That some mechanism of hereditary transmission besides chromosomes must be sought.

These statements do not seem to bear upon the subject of growth control; indeed they concern only the occurrence of leukemia without regard to its nature. In introducing the more analytical aspects of this study, I want to take you for a moment far away from leukemia—to a mountain top!

Imagine yourself on the highest peak in Norway. You are in a rope, tied to the guide who is chopping footholds in the upended glacier that crowns the summit. On the left the glacier sweeps suddenly down, on the right, a sharp edge—and beyond, space, reaching out to the bristling peaks and glaciers that ring the horizon. You are watching your footholds very closely. Suddenly you notice something dark just below the surface. It turns out to be the skin and skeleton of a rodent, somewhat larger than a mouse, with a short stubby tail and black and brownish markings.

You ask the guide, "Vaer sa god, hvad er det?" And he replies, "Ach, ja! Det er en lemming."—"Oh, a lemming!" And then you hear the story of the lemmings. How most years they are scarce, but every so often comes a lemming year, when they cover the mountains, stripping the alpine vegetation They are everywhere; in the wild heights, over the mountain pastures, a serious pest to the dairy farms. A disease breaks out and they die in great numbers. Water supplies become infected and every person in the mountains is liable to catch the dis-

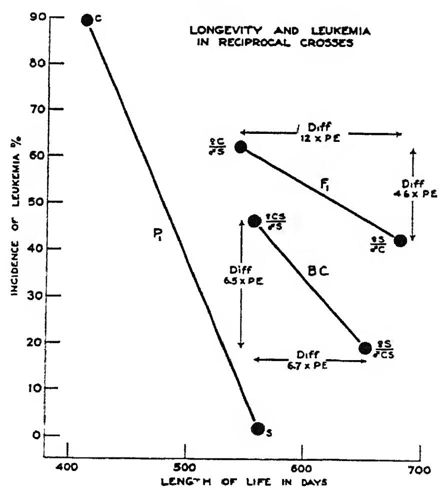


FIG. 6 GRAPH, SHOWING AVERAGES FOR INCIDENCE OF LEUKEMIA (PER CENT.) AND LONGEVITY (IN DAYS) IN THREE GENERATIONS, PARENTAL (P_1), FIRST HYBRID (F_1) AND BACK-CROSS (B. C.). STRAIGHT LINES HAVE NO SIGNIFICANCE BEYOND IDENTIFYING THE PAIR OF POINTS FOR EACH GENERATION. RECIPROCAL MATINGS IN BOTH F_1 AND B. C. SHOW REAL DIFFERENCES BOTH IN INCIDENCE OF LEUKEMIA AND IN LONGEVITY; THE TWO TRAITS ARE NOT CAUSALLY DEPENDENT.

ease, which lays him up for a few days with intestinal symptoms. But even so, the number of lemmings goes on increasing, until the search for food induces great migratory waves. These armies can not go far without coming to a cliff, and the pressure from behind is so great that they march right over the edge! Instead of a water fall, a stream of little animals plunges into the lake or fjord below. And the next year lemmings in Norway are as scarce as usual.

The stage is *now* set within a mouse; the players the leukemic cells; the wild growth of leukemia provides the motivation; and the problem, the analysis of the interrelations of the cells and their surroundings, whereby the leukemic cells escape the inhibitions of their environment, only to cause their own defeat by disorganizing the conditions necessary for their life The first step in this analysis is to separate the question of the origin of leukemic cells from that of their behavior by using cells that are already leukemic in transplantation experiments

Transplantation Experiments

If a bit of normal tissue is transplanted from one animal into another, under certain conditions, the transplanted tissue may survive for a long time, but its growth will be as limited as in the animal from which it came. But if the bit of normal tissue is placed in glass, with appropriate nutrient materials, it may exhibit continuous growth Normal cells have the inherent capacity for continued growth, but within an animal this is restrained by a regulatory control resulting from the organization of the animal as a whole.

Is the continuous growth of leukemic cells due to a change in this regulatory control or in the cells themselves? This question is directly answered by transplanting leukemic cells from a spontaneous case into a normal animal in which the regulatory control of tissue growth is patently intact. In certain animals the transplanted cells will continue their wild growth (see Fig. 7) Since normal cells could not do this, it is clear that leukemic cells are different from normal cells and that a change in the cells, rather than a change in the regulatory mechanism, leads to the disease

Since leukemic cells will continue their wild growth when transplanted into another mouse, it is possible by successive transfers from mouse to mouse to prolong indefinitely the multiplication of the descendants from the original leukemic cells Thanks to the consistency and specificity of the results from each series of transfers, it has been demonstrated that leukemia, as stated above, is indeed a disease of new growth By use of complete serial sections of organs of hosts killed at regular intervals after the inoculation, the leukemic cells were followed microscopically from the time of transplantation to the end Thus it was found that the leukemic cells invaded the host as though they were protozoan parasites; leukemic cells arose from leukemic cells and only from leukemic cells Even after passing through hundreds of successive hosts, in the course of many years, the leukemic cells are direct lineal descendants from the spontaneous case in which they originated. The change that rendered certain cells leukemic is inherited by their descendants indefinitely.

If genes were the only means of genetic transmission, we would think that this inherited change involved genes, but reciprocal crosses have shown that some non-chromosomal mechanism is also indicated. Genetic theory insists that the cells of different specialized tissues within an individual carry the same genes, so that some mechanism other than genes must assist in the origin and maintenance of these differences between tissues It is possible that the same mechanism is involved in all these cases Until evidence can be secured, the question must remain open: Is the property that distinguishes leukemic from normal cells transmitted from cell generation to cell generation by means of a changed gene or by some other

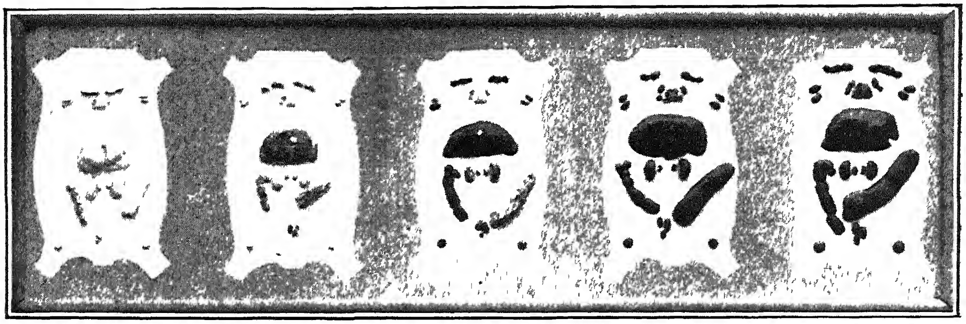


FIG. 7 MODELS OF ORGANS SHOWING DAILY PROGRESS OF LEUKEMIC CELLS AFTER TRANSPLANTATION INTO A NORMAL MOUSE.

mechanism of the cell? This same question applies to all mammalian tumors, it applies to the differences between specialized tissues within an individual; its answer is basic for theories of development and heredity.

Extrinsic Influences Upon Leukemic Cells

One of the most striking features of the transplantation experiments has been the difference between leukemic cells coming originally from different spontaneous cases. Differences between spontaneous cases have been mentioned, but little could be told of their significance by direct observation; such differences might be due to intrinsic properties of the leukemic cells, or to extrinsic modifications of their behavior. But now when certain leukemic cells reproduce the same picture in every mouse into which they are inoculated, and repeat this transfer after transfer, and when leukemic cells from other spontaneous cases in successive transfers reveal characteristic differences, one is led to believe that differences between spontaneous cases are in some way related to intrinsic differences in their leukemic cells However, the origin of these intrinsic differences in leukemic cells, within animals of uniform genetic constitution, must depend upon extrinsic factors.

The genetic constitution renders a certain type of white blood cell liable to undergo an inherited change, a change that enables these cells to overcome the normal control of their growth. But we believe the quality of this change depends upon extrinsic factors. When the quality of this change falls below a certain threshold, leukemia does not develop In this way extrinsic factors may control both the quality of the leukemic cells and the incidence of leukemia.

Genetic Control of Cells' Environment

But this is not the whole story. So far the environment in which the leukemic cells were growing has been held genetically constant, so that the influence of genetic variations has not appeared. But suppose now we apply the method of analysis by deviations to the genetic control of the conditions surrounding the leukemic cells that is, we will vary the genetic constitution of the host.

Transplanted leukemic cells of a given quality will grow in every mouse of strain A, while in every mouse of strain B their growth is restricted and they finally disappear. A leukemic cell leads to leukemia only in a favorable environment. One environment controls, another does not control leukemic cells. This clear-cut result indicates that this environment is regulated by genetic factors. In one particular case, a detailed genetic analysis was made, which showed that the favorableness supplied by one

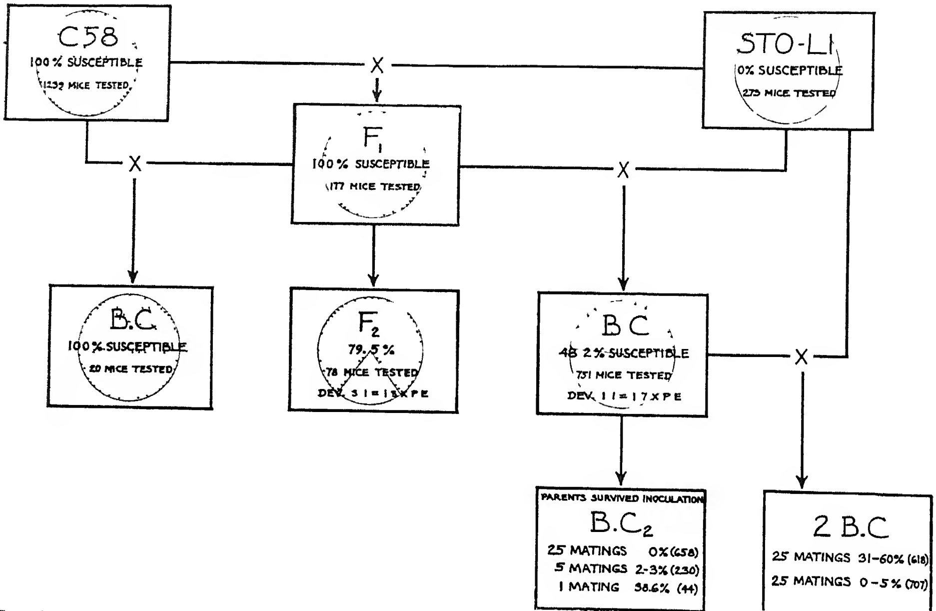


FIG. 8. EVIDENCE THAT ONE GENE DIFFERENTIATES SUSCEPTIBILITY AND RESISTANCE TO ONE PARTICULAR KIND OF TRANSPLANTED LEUKEMIC CELLS INHERITANCE OF SUSCEPTIBILITY TO INOCULATION, WITH LINE I, AS CONSTITUTED JAN., 1930–MAR, 1931.

strain of hosts in contrast to the unfavorableness supplied by the other strain of hosts depended upon one gene (see Fig. 8).

One gene could turn an unfavorable environment into a favorable one; in terms of the host inoculated with leukemic cells, one gene decided whether it would live or die. Such a simple result in the face of the obviously increasing complexities seems almost like a sudden rainbow of promise. Perhaps after all a powerful gene acting upon the mechanism controlling differential tissue growth may hold the final power. But hope soon dies. It soon appeared that this one gene had such significance for only one particular kind of leukemic cell; that other genes were necessary for other kinds of leukemic cells and that an environment favorable for one leukemic cell might be unfavorable for another. Thus there is no one set of conditions in the body that permits the wild growth of all leukemic cells; the required conditions vary as the cells vary.

EXTRINSIC MODIFICATION OF CELLS' ENVIRONMENT

The ability of the environment provided by the host to control leukemic growth is not determined by genetic constitution alone; here also extrinsic forces may operate At this point it becomes easier to speak in terms of resistance and susceptibility of the host A mouse naturally resistant to certain leukemic cells can be rendered susceptible, and a mouse naturally susceptible can be rendered hypersusceptible or resistant. Susceptibility has been induced by Krebs and by Furth, using radiation. Resistance in genetically susceptible animals has been induced by administration of such small numbers of leukemic cells that they did not become established and the mouse survived; then increasingly larger doses of cells were given until eventually the mouse could withstand enormous, massive doses of leukemic cells.

A more rapid induction of resistance followed treatment with certain normal tissues. A single treatment with embryo

skin will enable a susceptible mouse to resist a dose of leukemic cells that would kill every untreated mouse. But this resistance is not due merely to the introduction of normal tissue as such into an abnormal position (abdominal cavity); it depends upon an interaction determined by the genetic constitution of the mouse in relation to that of the normal tissue. If the mouse and the transplanted normal tissue have the same genetic constitution resistance may not be induced. Moreover, in some combinations of constitutions the reaction may be completely reversed, inducing heightened susceptibility instead of resistance. The identical normal tissue that induces resistance when transplanted into hosts of one genetic constitution may strikingly hasten the growth of leukemic cells in hosts of another genetic constitution. This is to say that the reaction of the mouse to one tissue may enable the mouse to resist or to enhance the growth of another tissue.

The different results given by treatments with different normal tissues symbolize the delicacy of the balance in the interaction of tissues Such interactions may well play a part in the control of tissue growth in the normal process of development. Instead of different transplanted tissues, we have the successive differentiations of specialized tissues which react with the embryo as constituted at the moment and enable it to depress or stimulate a given tissue. With the advent of each new differentiation the reaction system of the animal as a whole is modified, so that its power over the growth of different tissues is constantly changing.

In short, the environment of leukemic cells is a deciding factor in the outcome. Genetic factors may make this environment favorable or unfavorable, but in either case extrinsic factors may reverse the effect of the genetic factors. Treatments with normal embryo skin are among such extrinsic factors, but the effect of normal tissues as extrinsic factors depends in turn upon their genetic constitution. How far this analysis can be utilized in spontaneous cases remains to be seen.

Conclusion

In brief, leukemia depends upon changed cells and their environment. White blood cells are changed by the action of some extrinsic influence upon a genetic tendency to undergo a genetic change. The specific quality of the changed cells depends upon the specific quality of the extrinsic influence. The environment of the changed cells provides a differential control over tissue growth. The change in the cells may or may not enable them to escape this control and to grow wildly. If not, some subsequent change may give the power to overcome this regulatory mechanism. This regulatory mechanism is itself under genetic control and it is also subject to modification by extrinsic influences that may reverse the effect of the specific genetic control. This mechanism is a product of the combined tissues of the body as organized into a whole; its power is built up by countless interactions of tissue upon tissue; these interactions in turn depend upon intrinsic properties as well as extrinsic conditions

At every point a given intrinsic influence depends in its operation upon the extrinsic influences encountered. An intrinsic condition has arisen as an extrinsic modification of a previous intrinsic condition; an extrinsic influence may itself be intrinsically controlled and extrinsically modified.

Such are the interactions of influences operating in the disease leukemia; such, very broadly, are the interactions of influences in organic development, in the ecological relations of organisms, in the case of the lemmings in Norway, in human behavior In organic development the extrinsic factors in a given

process are coordinated by antecedent intrinsic factors, while in mental development the extrinsic factors lack this unifying principle But even so, in mental development as in organic development a given reaction leaves its effect, so that the individual is no longer the same; the next reaction is between the changed individual and the extrinsic factors The behavior of man is just as much a resultant of intrinsic and extrinsic interactions as the behavior of leukemic cells

The rôles of intrinsic and extrinsic factors are marvelously interwoven. In the improvement of man we deal mainly with extrinsic influences. But if we are to deal wisely with these, an understanding of intrinsic limitations is essential From the standpoint of our findings for mouse leukemia, the control of genetic factors has been the outstanding basis of progress. This control has revealed the operation of extrinsic influences on all sides; *their* control may mean the control of leukemia.

Thus a geneticist studies leukemia. But by the side of the geneticist a pathologist has also studied, and a cytologist and a physiologist And each of these has made important contributions to the account that has been given, but each one also faces his own special problems and has his own account to render. At present chemical questions are becoming more and more numerous, when it becomes possible to include a biochemist in the work of this cooperative group, the rate of advancing knowledge should distinctly rise For it must be clear that the processes involved in leukemia lead us to the basic processes of living matter, and if significant advance in the understanding of these processes is to be made, it will require the concentrated and concerted efforts of many approaches and many forms of technique

IN QUEST OF GORILLAS

IV. JOYOUS DAYS IN THE KIVU COUNTRY

By Dr. WILLIAM KING GREGORY

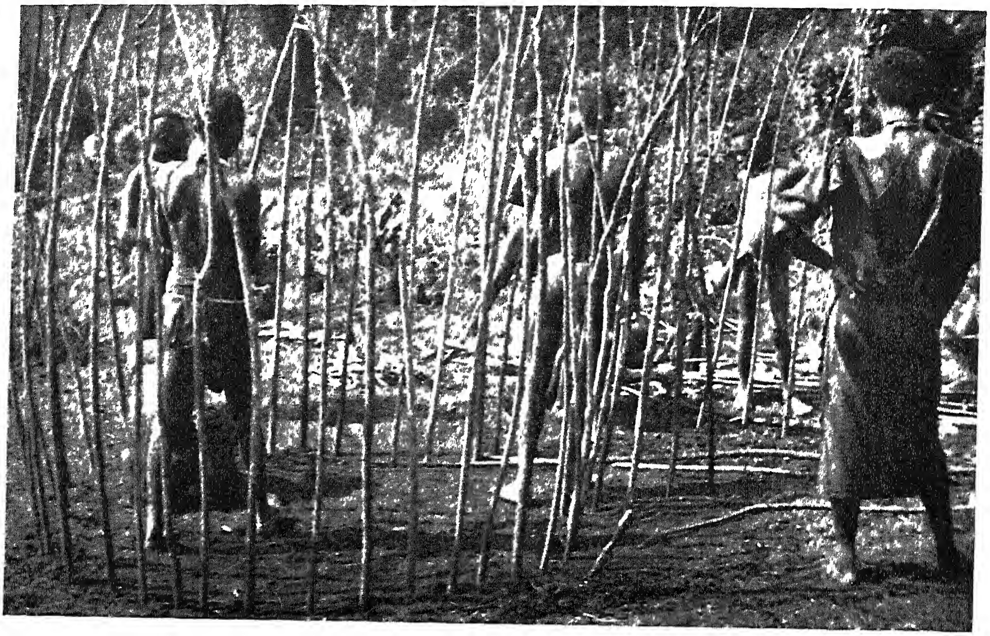
CURATOR OF COMPARATIVE ANATOMY AND ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

THE six weeks that we passed at Tschibinda were so crammed with interest that it is difficult to be brief without losing the freshness of the reality. The place that Raven chose for our camp was in a spot that was ideally beautiful and highly convenient Immediately behind us was a broad zone of thick jungle of second growth, dotted with many kinds of flowers and covering many acres; behind that was the "gorilla forest," stretching up to the serrate skyline of the mountain. In front of us was an open field of dark brown earth sprinkled with green herbs of various kinds. This field led away from us downward toward the lake, into a fertile little valley which increased in width and depth as it receded from us and was gay with *Erythrina* trees and with light green plantain plants; many of these had erect leaves, some twelve or fourteen feet long At the right above this valley was a low mountain, dotted here and there with trees. At the left of the valley was another convex elevation with a flaming *Erythrina* tree standing on the top. At the left of this elevation in turn were the sloping, undulating fields of the farm, rising into a good-sized hill at the extreme left.

In the distance in front of us and beyond the brown field was a panorama of lake and mountains, the colors of which changed daily as the hours passed. In the early morning silvery mists would often veil but not obliterate the mountains, which were arranged in purple grays of progressively fainter and more hazy tones, so that one could see eight or more planes, one behind the other. In the midst of the morning sunlight the

—*Photograph by H. C. Raven*

ERYTHRINA TREES IN FRONT OF CAMP.



NATIVES BUILDING HUT —*Photograph by H. C. Raven*

mist was thinner and more diffused and there were soft tapestry effects; first the near-by mountains, then the dark lake, then the cut-out-looking, pale greenish-brown mountains on the other side of the lake, then the paler ones in the distance. Our beautiful *Erythrina* tree at the left of the center at such times would glow with color against the tapestry of the background. Above all this, in the entire upper half of the picture, were piled Olympian masses of billowy white clouds, flashing against the cerulean blue.

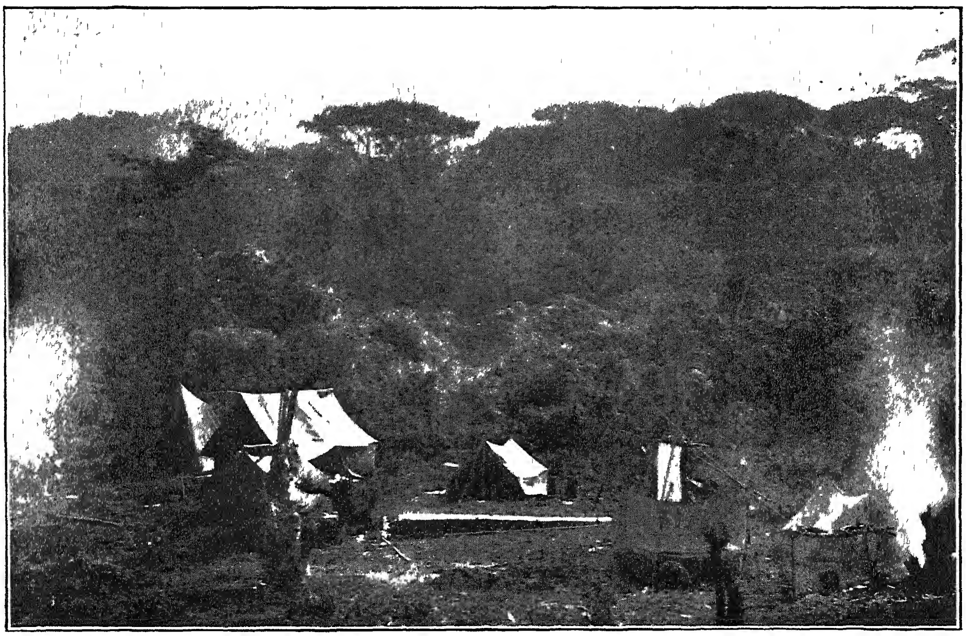
The whole picture was too immense to show in a photograph. The eye had to wander about over it, while the mind admired the cumulative effects. Late in the afternoon a curtain of mist would often be hung over the distant mountains, and then our *Erythrina* tree would be dark but sharply silhouetted, revealing every cranky angle and twist of its greater and lesser branches and twigs. Nor shall we ever forget a group of three slender trees on top of a rise near the middle of the view from our camp. Bowing demurely toward the mountains, they sent up their light curving stems and from their white upraised arms flung upward a scattering flare of twigs and leaves outlined against the sky

But there was much to do in camp. While Raven was off hunting gorillas, Engle and I were at work getting Dr. Morton's records, or McGregor and Engle were busy developing the large number of cinema and still negatives already taken. For each of these activities special arrangements and constructions had to be made. In order to have porters ready to cut paths and to bring the two gorillas into camp whenever we should get them, it was necessary to keep with us forty porters, which the district administrator had sent to us from a distant village. They built huts in the little valley immediately in front of our camp First they cut slender stems and lopped off all side branches. Then they jammed the stems into the ground in a circle, bent the tops of the stems in toward the center and tied them together at the top.

Next they put pliant stems in horizontal zones, weaving them in and out between the verticals. Thus a dome-like basket was formed, with an opening for a door, the joints being tied with twisted plantain leaves. Then they took plantain leaves from eight to fourteen feet long and covered the basket, twining the stems into it, layer after layer, until a fairly rain-proof hut resulted.

Several of the men carried water for the camp, one or two shredded the fiber from banana leaves and twisted it into twine for themselves and us. Two or three were sent at times to Bukavu, twenty-seven miles away, to bring back boxes of groceries and cans of gasolene, etc., on their heads The forty were in charge of one policeman, representing the government, who tried to prevent them from deserting us by threats of imprisonment However, we could not fairly expect them to stay more than a couple of weeks, after which we had to get a new lot from somewhere else. They were all most punctual in lining up every few days to receive their pay, which was mostly for the highly congenial work of absorbing an enormous number of sunrays in their black pigment. But when the great day came and Gorilla No. 1 was to be brought into camp, we could muster only nineteen of them, when twice that number were badly needed. At night they would huddle about their fires and then pile in to pack themselves in their little huts.

Meanwhile, however, Dr. Engle and I had literally put them through their paces for Dr. Morton. First we built a level raised path about twenty feet long, upon which we spread out the folding set of boards Dr. Morton had given us Several men would fill little baskets with earth and throw them on the ground between the parallel strings we had stretched there. Of course there was a crowd of other natives looking on. As there was need of tamping down the earth, I started to stamp on it and clap



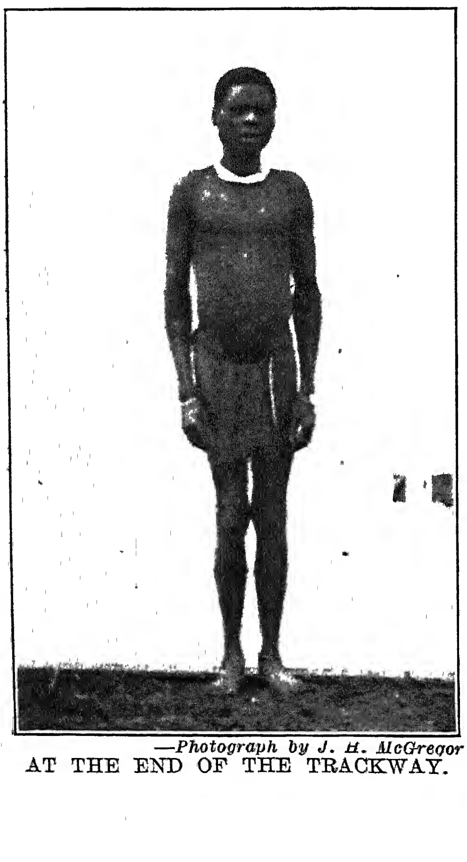
—Photograph by H. C. Raven

OUR CAMP AT TSCHIBINDA.

THE STRAIGHT TRACKWAY COVERED WITH WHITE PAPER IS SEEN IN THE MIDDLE FOREGROUND.

my hands, seizing a couple of sticks and beating an empty box to imitate a native dance. In a few seconds the mound of earth was covered with a line of grinning savages, stamping and writhing and singing in time with the drumming, which was now being done by one of our own boys, while McGregor was spinning his cinema When all this was done we spread the row of jointed boards on the mound and were ready to begin operations. Meanwhile we had supervised the erection of a lattice against which was hung a screen marked with squares, from which one could read in the photograph the approximate dimensions of a man standing in front of it.

When all was ready we lined our blacks up and stood them, one by one, in front of the screen, photographing them in front, side and back views Then we spread a strip of inked cloth over the board walk and over this a strip of white paper held in place by strings and stones. Now our native walks along the paper pathway leaving his footprints, first without a load, then with a load of forty pounds on his head, while McGregor makes a cinema record and Engle makes still photographs I change the large numbers (which serve to correlate the photographs and footprints), enter the data in a notebook, take the measurements and show the men, women and children where to stand and when to walk along the board walk Each individual, big or little, receives one franc. Those with missing toes (often due to yaws) or other peculiarities also have their feet photographed. All this takes a lot of time as the wind blows up our paper track, dust falls on the ink strip or rain stops the performance in a hurry. In time, however, we get all our porters and village folks recorded, as the good news of "one franc each" is spread. It was a banner day for this work when the Batwa (pygmies) that had been hunting with Raven came with their dumpy little wives and tiny children to walk over the white track



—*Photograph by J. H. McGregor*
AT THE END OF THE TRACKWAY.

It is impossible to convey the amusement we derived from seeing each one of these strange beings that lived in a world so extremely different from ours. Let us consider, for example, a great half-circle of our porters and trackers squatting around us on the ground, watching us seated at the breakfast table and waiting for the glad moment when they should stand in line and receive four days' pay (four francs each) from the white man with the shining head (Raven). There is one youth, my special pride and joy, who has one of the most primitive gorilloid noses I have ever gazed at. This proud trait of ancient anthropoid lineage was exceedingly wide at the base, almost as wide as his mouth, with the nostrils facing distinctly forward; the tip of the nose very low (for a human, but well advanced beyond the gorilloid stage), while the wings of the

—*Photograph by H. C. Raven*

MAMBUTI OR BATWA?

THE PYGMIES WEST OF LAKE KIVU ARE NEARLY INTERMEDIATE IN GEOGRAPHIC POSITION BETWEEN THE TRUE BATWA, SOUTHEAST OF THE CONGO ESTUARY, AND THE MAMBUTI OF THE ITURI-UELE DISTRICT. THE PYGMIES ARE WIDELY DISTRIBUTED IN THE FORESTS OVER THE CONGO BASIN.

nose were very wide. Near this youth sits a man with almost the opposite combination of features, namely, a sharp, delicately modelled and (for a Negro) narrow nose set above a fairly creditable mustache and a straggling chin beard. Does this man bear the blood of Hamitic or Semitic invaders from the east and north? Here is another boy with a placid, bovine face, very long and flat, with wide cheek bones; his central upper incisors are very large and his rather small mouth and half-opened thick lips give him an amusing pseudo-mongoloid and semi-idiotic expression. Next him sits one of the elders, reverend and venerable, his face very long and drooped, with exceedingly deep wrinkles across his forehead and around his eyes and mouth. His forehead is bald, nose very wide, recalling that of a five-months' foetus; he has large malformed incisors and projecting ears. He sits crouching with downcast eyes and hands clasped as if in prayer—a poor old Job sitting amid the ruins of his prosperity.

Here sits erect an immense man, Buddha-like in a way, but with an enormous gross face and incorrigible, leering eyes. This black Gargantua thinks perhaps of all the pombé that four francs will buy and inwardly licks his chops. Near him is a Caliban, with broad simian face. This man, by the way, was one of the patients at our involuntary clinic. Yesterday he came again to make the most expressive grimaces and gestures to show where the pain was in his poor old back; and was mightily comforted when we smeared it with iodine and even slipped him an extra franc. Then there is a tall and very skinny ancient who understands a joke. When he had received an aspirin tablet from us for his pains he

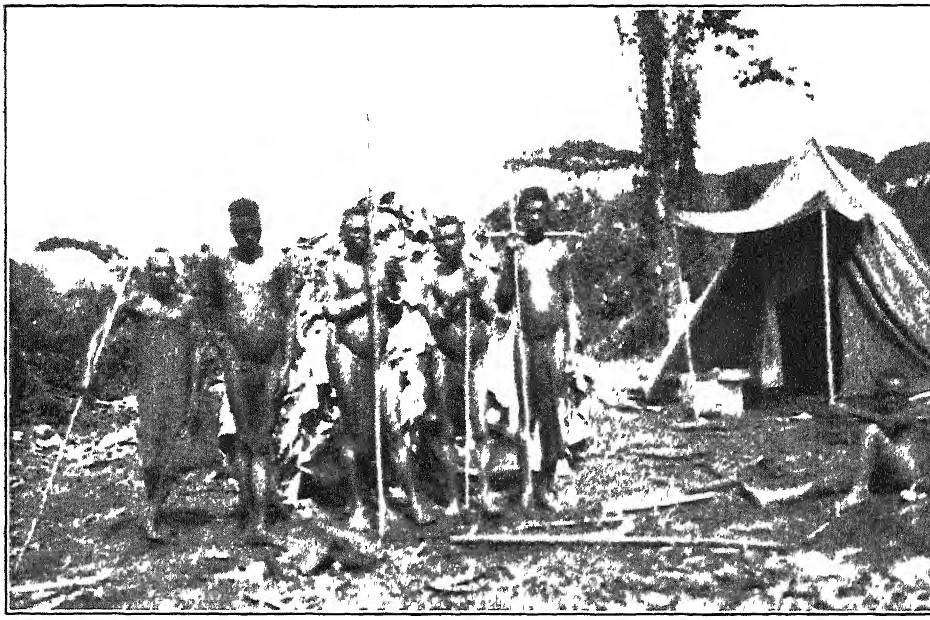
grinned knowingly when we gestured to him that our fee for medical treatment was one franc.

Our Batwa (black hunters) are in a little group by themselves, standing with spears erect, watching all that goes on with the keen eyes of hunters. They are supposed to belong to a tribe of forest-living pygmies, but they range from real pygmies to medium-sized people and although they speak a different dialect, they seem to have intermarried with the ordinary blacks. One of their leading men, Nyumba, for example, is by no means a dwarf but a middle-sized man of fine proportions and beautiful muscles. On one wrist is a great brass bracelet. His almost aquiline nose gives him an alert and at times fierce expression. Yesterday he gave us a dramatic and thoroughly convincing representation of himself attacking another man or perhaps a leopard. Snarling and showing his canine teeth, he stamped and raged about the field, zigzagging his flashing knife-point above his head and stabbing with tiger-like ferocity and quickness. But now he sits benignly with the good nature of health and self-approval.

Next to him is Chiliganoa, the Prince Charming of the Batwa, perhaps the most graceful and Adonis-like figure we have seen outside the Luxembourg gallery of statues. Fortunately he is either too poor or too proud to ruin his beauty by wearing white men's clothes; his thin girdle of bright beads well becomes his sable body, while a thick magenta-colored necklace sets off his finely chiseled face. Then comes Nyarikengua, one of the elders of the Batwa, a delicately-formed little old man with narrow, thoughtful-looking face, relatively small thin lips and a projecting chin. Then Karrara, a very friendly little old kobold, with wrinkled face and a slight beard. Then Jukulu, the most comical of all the Batwa, a little middle-aged dwarf with thin chin whiskers and baby-like hands, quite a beau in a small way, with a voluminous dark-blue toga. What a treat it was to see him imitate a gorilla, slapping his chest, making a clucking noise with his lips and running forward in a half-stooping posture. Here would be a cartoonist's idea of the "missing link."

Finally, in front of all these and with a couple of his quaint little boys behind him, sat Cassoura, the little old chief of the Batwa, with the most pithecoid face of them all; enormous wide mouth and broad nose, deep wrinkles on the forehead, on the cheeks and around the mouth, projecting ears and a crown of black wool on top of his closely shaven head.

The people that worked on the agricultural farm also furnished their quota of amusement. Our tents were set on the edge of a field which had been cleared of trees and was finally prepared for agriculture during our stay there. After the stumps had been dug out and stones had been removed, a double row of perhaps twenty-five men armed with hoes began work at one end of the field near our tents. The babel and uproar which arose and continued in undiminishing volume were astounding. The noise of a lot of schoolboys suddenly let into a narrow schoolyard for recess would have seemed dim and far away compared to this. One wondered whether some one would get murdered, but experience showed that each man in each squad merely wanted at all times to be heard and realized that he would have to compete with all the rest. Finally the man in charge would get the line fairly quiet for a brief moment and give the word to go. Up and down flashed the hoes at irregular intervals (the more irregular the better, so far as Private Broadnose cared), but the tongue work was never done. Forward moved the line as slowly as was humanly possible. But at the end of a few hours of this exercise with voice and hoe, the field was well hoed



—*Photograph by J. H. McGregor*

OUR BLACK HUNTERS.

and the shouters were moved away to a less dangerous proximity to our ear-drums.

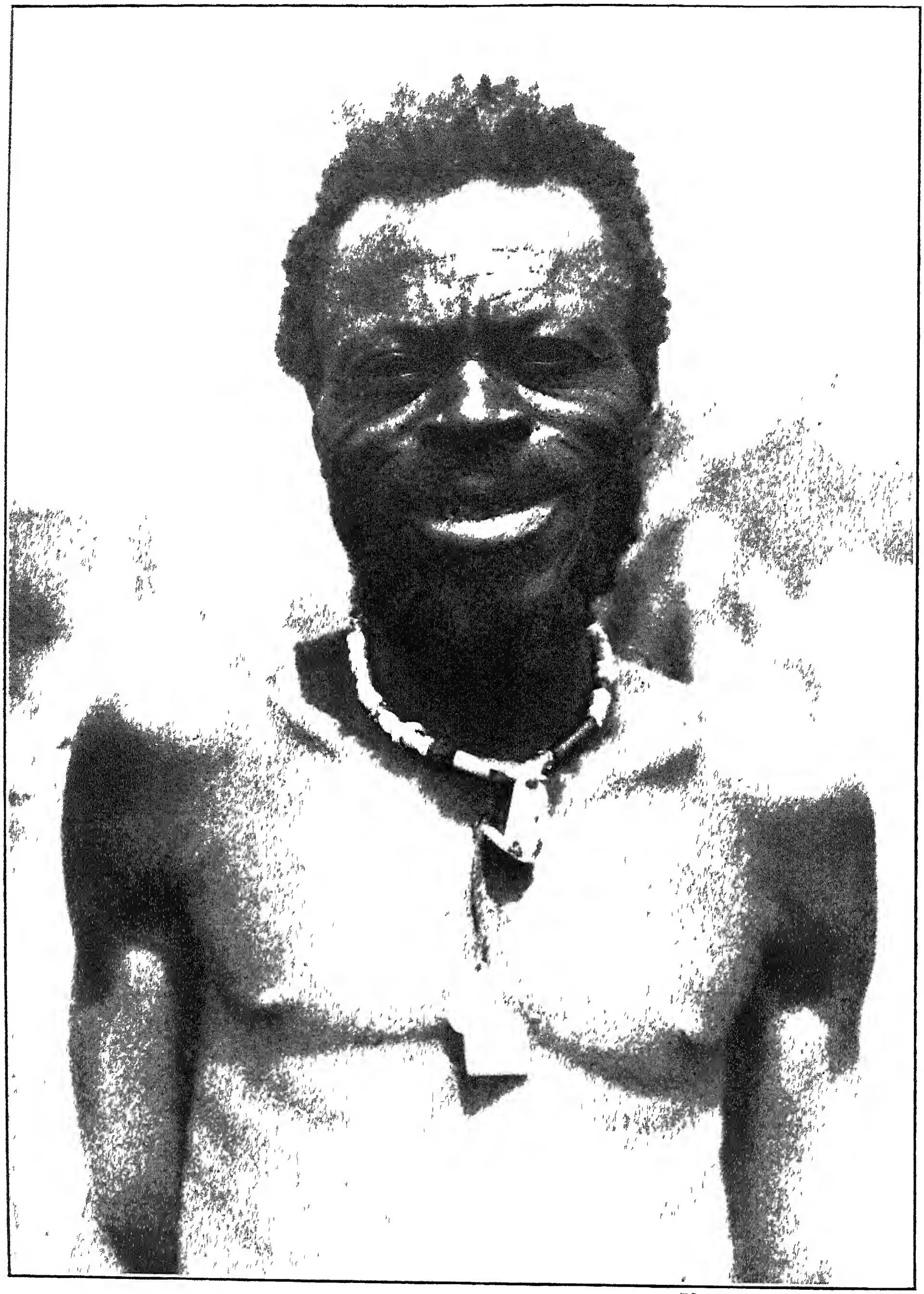
This same field furnished another little scene of human interest. It was traversed by a narrow, very deep, irrigating trench, easy enough for an adult to step over but a formidable obstacle to little folk. Over this trench at its deepest part straggled a woman and three children, each with a water pot on his head, adjusted to size. Baby wobbled along, bringing up the rear with a carefully poised tomato can. Mother and the older children got across the ditch; but Baby found himself cut off by the awesome abyss. Dear me, what a howl he put up. "Help! Help!" One of the older children turned back and lifted him over. In a little while we saw them all coming back from the spring by another route, each with all the dignity of one who walks down a steep hill with a jug of water on his head.

Nor were our excursions to the native villages in the vicinity of Tschibinda less interesting. In many places several families would live within a stockade of light sticks enclosing their houses; these were circular in form, with straw-thatched roofs. Sometimes there would also be miniature houses, occasionally containing fruits and other offerings to the spirits. The houses had neat little doors which could be set in place at night. A fire could be lighted in the middle of the house by the skilful natives without setting fire to the straw roof. Sometimes one would see very old people leaning feebly against the huts. Many babies have dreadful sores, running eyes, etc., and some of them lose a toe or two from yaws. But all bear suffering stoically and snatch what comforts life may bring.

At night fires gleam, the box-pianos drone and the people gather in a circle, while the drums keep up an incessant theme:

Tump-a-tump, tum, tum, tum!
Tump-a-tump, tum, tum, tum!

with droning and clapping chorus.



—*Photograph by E T Engle*

A TYPICAL BATWA HUNTER

In general their household effects seemed to be far simpler than those of the people along the Congo River. They use large hollowed gourds to hold water, instead of pottery, and the decorations on these consisted chiefly of obliquely incised lines, said to represent a garden. They make neat matting with little, if any, decoration. They have elongate leaf-shaped knives in wooden scabbards, decorated with incised lines and projecting points. They sold us some neatly woven rattan boxes with hinged lids and clever devices for fastening. Some of the tobacco pipes which we bought had a reed stem and a blackened, well-turned clay bowl, ornamented with a finely woven band of iron wire. At Nakalongi, not far from Tschibinda, Raven and Engle found the native iron-smiths shaping their knives. The most ingenious native iron implement was the "mgoosu" described below.

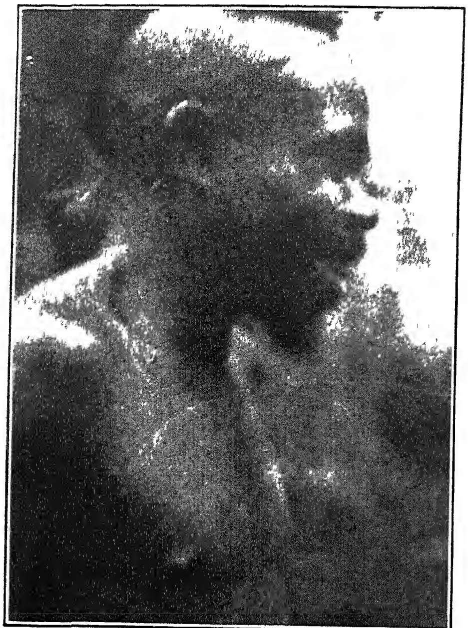
A walk to a native market, which was about nine miles northeast of Tschibinda, also yielded some interesting glimpses of the natives. As we were in need of meat and wanted to see the country, Engle, McGregor and I took several of our porters and one of our boys to carry our cameras and whatever we might purchase in the market. We had to descend from our camp in the mountains to near the level of the lake, then walk north over a hilly country, then ascend a very steep hill where the market was held; on the way back we had to climb about 1,500 feet at the very end of the trip.

Although we did not arrive at the market until long after the peak of its activity, we could hear the buzz of the all-talking public as we toiled up the steep slopes of the young mountain on which it is held. We did not wonder that some of the women who had carried huge loads up this steep ascent had left their babies in care of several other women whom we had seen minding several babies in a sort of impromptu day-nursery under a shady tree near the foot of the hill

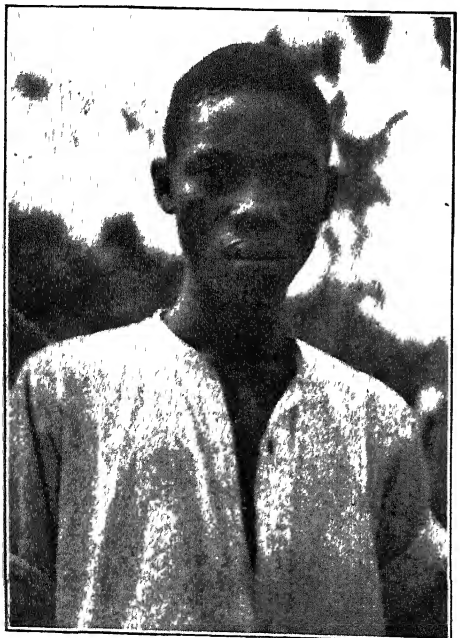
When we arrived at the top we found a milling crowd of black humanity, which on the whole was not very different from that which we had seen on the market hill in Bukavu. But unlike Bukavu there were no shops here, so that many black merchants had spread out their little stocks of dress-goods, small mirrors, beans, cotton thread, salt cakes, etc., on the ground. There was little if any sale of articles of native manufacture, for which the demand seemed far less than that for foreign merchandise. Our own purchases were limited to a goat, a couple of kids, some beans, etc. McGregor did a lively business in purchasing cinema views of the folks that shuffled about, especially comical old men and assorted women with babies.

Soon after midday we started on the long trek back home; but now we were traveling like pilgrims in a stream of humanity. The women carried their loads of purchases, leaning far forward when going up hill, often with a big baby perched contentedly on top. Among our own followers was little Jukulu, the stout pygmy with short chin whiskers and chubby hands. He had purchased some brilliantly blue cloth, which was now wrapped in graceful folds around his plump black body. He strode along with great satisfaction to himself and to us, skilfully guiding one of the goats with his long wand. We passed a bush fire, which was crackling merrily, but nobody seemed to mind Then we passed a company of agricultural workers, who were emitting the usual babel. But by the time I had reached the middle levels of our mountain I was interested chiefly in the struggle of forcing myself up the remaining steep slopes leading to camp.

By no means the least entertaining feature of our life at Tschibinda was



—*Photograph by H C Raven*
JUKULU.



—*Photograph by H. C Raven*
POUSSINI.

the opportunity to observe and study our four boys. Poussini the cook, the oldest of the four, who came from near Usumbura, was a slender young man with a long face and a chronically dejected mien, who simply could not be hurried In a quiet way he was very fond of pombé and of female society. Although always complaining of feeling ill, he never failed to have his fires going and hot meals ready within a reasonable margin of delay, considering how often he was hampered by rains, etc. He took his profession seriously and had a considerable flair for making bean soup. His oatmeal at breakfast was really a triumph. He could not fairly be blamed if the meat of goats and even of kids was unbelievably tough. His greatest ingenuity was displayed, not in making a fire out of wet wood in a pouring rain, but in making some assistant that he usually managed to annex carry water, chop wood and do all the menial work.

Musafiri, Mr. Raven's boy, came from near Baraca on Lake Tanganyika. He was very short, with a great round face and large black eyes. He was easily teachable and did almost everything well that he was taught to do; although fairly slow, he was on the whole rather intelligent and honest.

It was amusing to see the tolerance for fire that Poussini and Musafiri demonstrated by passing their bare hands and feet nonchalantly through the blaze of the campfire, around which we sometimes gathered in the cold mountain evenings, to the amusement and satisfaction of both parties. On one occasion I ostentatiously pretended to imitate them, making very deliberate passes at a safe distance from the flame but exceedingly swift movements when passing through it. This gesture brought out a salvo of laughter and a heartening display of ivory teeth and glinting eyes.

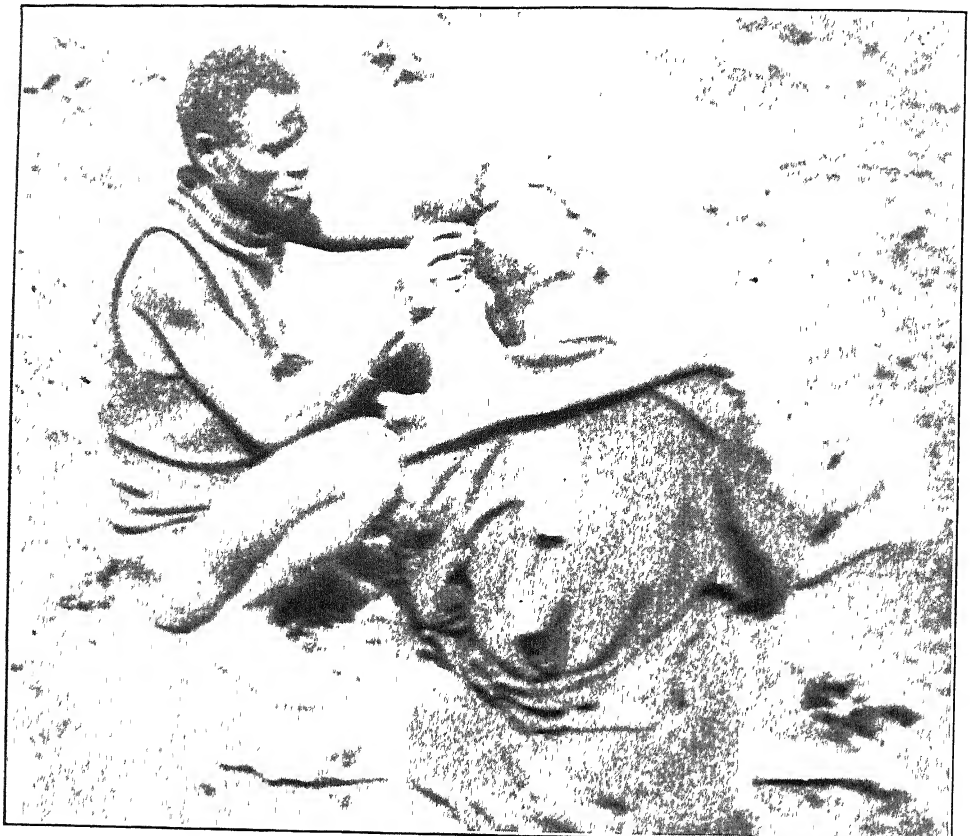
Like other travelers in Africa we soon came to feel an affection for these faithful and amusing creatures, who had elected to follow us wherever we should lead them in the great world Eventually Raven asked them what were their names for each of us. They told him that his own name was Bwana Para (the bald one), McGregor was Bwana Kitoko (dandy), Engle was Bwana Kapatura (short pants), while I was Bwana Tupi (short).

Behongo, the third of our four boys, would have won the approval of Julius Caesar, who is reported to have said, "Let me have men about me that are fat—sleek-headed men and such as sleep o'nights" Behongo had beautiful dental arches and a comforting smile. In fact I felt that he was almost worth his salary on this account alone. His forte was the laundry work, which he did to our complete satisfaction. At the Catholic mission he had learned to read and write well and could make out a neat bill itemizing the cook's expenditures for food, etc. He went with Mr. Raven on the excursion to Mt. Nakalongi and did excellent work in impressing the people of the neighborhood into helping to carry the gorilla. We all felt sorry when Behongo decided that he had better not go with us on the long journey across Africa, as he had a wife waiting for him in Uvira and a pair of fond parents who, so we were told, were serving a term in prison for eating somebody. Poussini, on the other hand, was free to go with us, as his wife had gone off with somebody else while he was away and he didn't have to bother about alimony.

By far the funniest of our boys was Dr. Engle's boy Matambele. He was very slender and immature, with a swelling abdomen, always gesturing with his long angular arms and slender hands and pouring out a flood of comical language in a high-pitched voice. What a hit he would make on the vaudeville stage! He was the politician and financier of the group and far excelled the others in the art of making the Wapakazi (common "work people") draw water and hew wood for him. He delighted in having hot coffee at our bedsides before breakfast, when we first awoke in the chilly mountain air, and was quick to serve us and even to anticipate our wants. His appearance on one of the nights when

—Photograph by H C. Raven
MUSAFIRI AND BEHONGO.

he went to a dance at Tschibinda was inimitable. His protuberant abdomen was gracefully covered with a white evening shirt and a black vest with sharp points, which he combined with very short khaki breeches. Dr. McGregor and I gave him a white collar and a bow tie and after we had trussed him up in these I got out my shaving mirror so that he could gaze at



—*Photograph by E. T. Engle*

REAL COMFORT

all this dazzling array. His rapture was complete when we gave him some francs to buy pombé with.

As to the matter of honesty, there were numerous small things about camp that our boys could have stolen if they had wanted to, as it was impossible to keep watch all the time. But we never missed anything, not even francs or half-francs, of which we had to keep a large supply to pay the porters with. We did not attribute superhuman virtues to them, however, and took reasonable precautions against thrusting temptations before them.

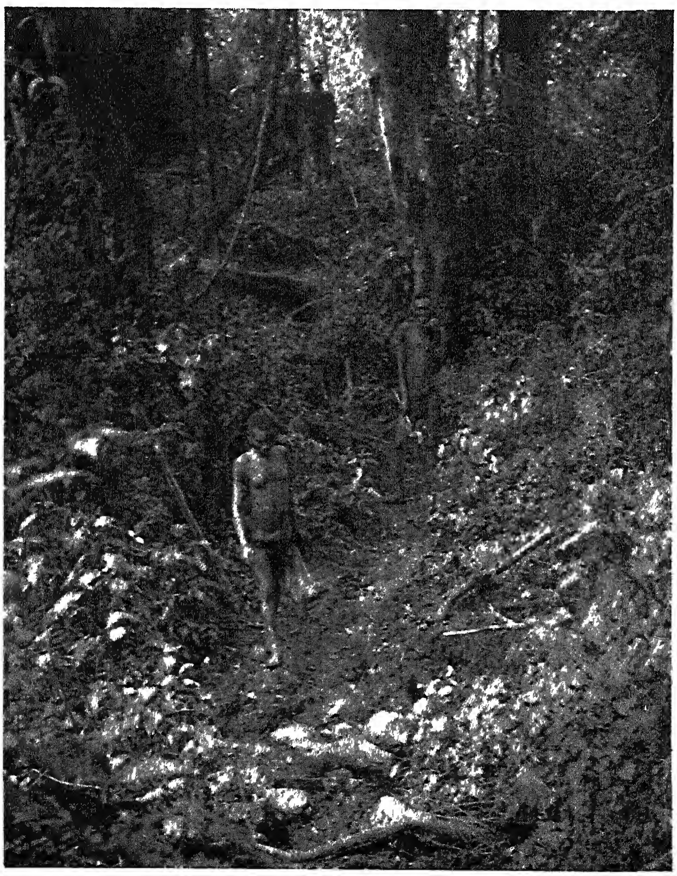
I am bound to admit that the natives of Tschibinda, so human and yet so unlike anything we had known, derived equal amusement from looking at us, either staring blankly at the meaningless things we were doing (such as washing negatives and hanging them on a line), or inspecting our strange apparatus. But the gleam of real desire only flashed when they saw a fine, newly-emptied tin can or a discarded razor blade.

The natives at Tschibinda constantly made use of a remarkable implement called a "mgoosu," which enabled them to clear a path quickly even through the thickest underbrush. On the end of a long wooden handle was a shaft of native iron, having near the lower end a long, one-sided blade, and beyond this at the tip a small crescent or sickle with sharply concave edge. A quick swish of this implement while using the sickle part would cut through all thin vines and

branches, while a smart cut with the long blade would eat into a sapling or stout branch I bought one of these implements from a native and began to cut paths through the jungle immediately back of our camp. The top of this jungle growth in most places was away over one's head, so that going about in it was like navigating on a black night; it had to be done by a sense of direction, which I mostly didn't have.

One day I came to a place very near our camp, which with a moderate amount of work gave me a beautiful "jungle studio." There was a "rotunda" with a natural opening in the center, draped with vines and flowers; through this the sun filtered down to a circular space which I cleared below. A curving path through the jungle and an archway of vines and branches led to the rotunda and a long curving tunnel made an exit behind it, while several bays and exits led off to paths on either side. In fact, many paths, that I cut as time went on, led from this center to various parts of the forest near by. Here I could sit and write, away from the clamor of camp, while many birds flitted in and out and large-eyed wood-mice crept about.

No dangerous animals ever presented themselves to view. Perhaps it was the



—*Photograph by H C. Raven*

A JUNGLE PATH.

THE TRAIL IS MADE BY ELEPHANTS AND FOLLOWED BY GORILLAS. THE MAN IN THE CENTER CARRIES A *mgoosu*.

—*Photograph by E. T. Engle*

FERNS NEAR MY JUNGLE STUDIO.

wrong season for snakes; at any rate, I never saw one in all the many days that I was rambling about in the jungle and forest. Leopards there might be, perhaps, down in the open fields far below us. We could sometimes hear them yowling at night. Gorillas, unfortunately for me, didn't care for that kind of place, which was too near to human dwellings, but preferred to roam in the forest behind it. The buffalo, a really dangerous animal, was excessively rare in this locality. In all his wanderings in the neighborhood, Raven saw buffalo tracks only once. Elephants appeared once or twice in the vicinity but all too briefly.

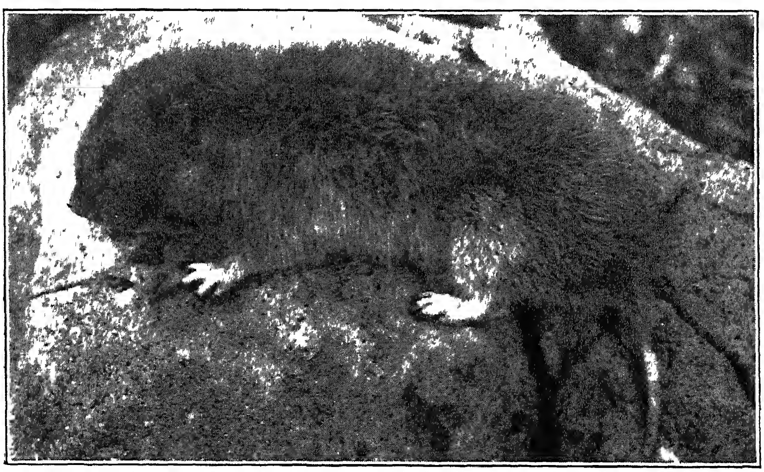
In fact, the conventional idea of Africa as a place swarming with dangerous animals, big game, venomous snakes and cannibals, was contradicted by experience on every day of our travels on that continent. These things still exist but in a rapidly diminishing number of localities, while by far the most dangerous creatures are, as always, the amoeba of dysentery, the tsetse fly and the invisible hosts of pathogenic bacteria.

The small mammals, birds and reptiles of Tschibinda were also of considerable zoological interest. We had been there only a short time when some one spoke of a "mole" (taupe) that dug tunnels in the fields. As true moles are not found anywhere in Africa, we suspected that some other kind of animal—presumably a rodent—was passing itself off as a mole. Soon the natives brought in a succession of these "moles," which were mole-like in a general way, having the body stout and short, head blunt, eyes very small, fur very fine. But they

differed completely from moles in having a rat-like head with greatly enlarged chisel-like incisors, by means of which the animal easily cut the stout roots that permeated the soil. The front paws were stout, with well-developed claws but not shovel-like, as in the true moles. McGregor got some excellent cinemas of this rodent (*Georhychus*) as it rapidly scratched and gnawed its way, first making a ditch and then quickly sinking out of sight.

Another and much rarer "mole" in this district was a northern relative of the golden mole of South and East Africa One living specimen of this curious little animal (*Chrysochloris*) was brought in by the natives and we studied its movements with keen interest. It has a short round tailless body with a conical head and beautiful soft fur, which gives rise to diffraction colors. In contrast with *Georhychus,* its front teeth are minute and delicate and instead of using them to dig with, it depends upon the greatly enlarged claws of its forefeet, with which it can dig trenches and tunnels with amazing celerity.

The occurrence of this animal in the region of Lake Kivu, so far away from the headquarters of its family, brought to the foreground the much discussed question of the origin and history of this family. Undoubtedly the golden moles belong to some group or stock of mammals that has no special relationship to the true moles of the northern hemisphere. Moreover, they resemble the true moles only in such features as are obviously related to the habit of digging in the ground, and we know that in many well-established cases such resemblances have been brought about by convergent evolution between animals of widely diverse origin in adaptation to similar habits. On the other hand, the golden moles also possess a long series of peculiar characters in the skeleton which are collectively found elsewhere only in the families of the tenrecs and their allies of Madagascar, as well as in the so-called otter-shrews of the Belgian Congo. It has therefore been inferred by many authors that the golden moles are the digging, or mole-like representatives of the tenrec family, just as the otter shrews are undoubtedly its semi-aquatic offshoot But Dr. Robert Broom, the well-known anatomist and paleontologist of South Africa, has discovered that the anatomy of Jacobson's organ in the nasal cavity of the golden moles is very peculiar and



—*Photograph by H. C. Raven*

A MOLE-LIKE RODENT (*Georhychus*).

—*Photograph by J. H. McGregor*

YOUNG GENETS.

widely different from that of the tenrecs, and he therefore concludes that the golden moles are not, after all, related to the tenrecs. Most students of the problem will, however, be inclined to conclude that this one conspicuous difference, to whatever it may be due, is far outweighed by the many deep-seated and peculiar resemblances that seem to tie the golden moles in with the tenrec family.

Another species of animal that was brought into camp at Tschibinda by the natives was a genet, a small carnivore, a member of the civet family (Viverridae). At the present day this family includes such interesting animals as the suricate of South Africa, a friendly little beast immortalized in Olive Schreiner's "Story of an African Farm," the mungoos of India and Africa, famous for its attacks on poisonous serpents, the genet of Europe and Africa, and the civet of Africa, whose glands yield the base of many perfumes. In Madagascar the family has many representatives, varying from small genet-like forms to the cat-like foussa. Long ago in the days of the four-toed horse (the Eocene epoch of the Age of Mammals) there was a family of carnivores in Europe and North America, in some of which, named *Viverravus* by the late Professor Marsh, the jaws and teeth approached those of the existing civets and genets. The two beautiful little genet kittens which were brought to us alive in our camp at Tschibinda were thus the heirs and living representatives of this extraordinarily ancient family, so it is no wonder that we studied them with keen interest. Their gray fur bore dark, somewhat irregular spots which tended to be arranged in incomplete longitudinal streaks. This is the pattern which is generally believed to have given rise to the more specialized fur patterns among the cat-like carnivores, such as the sharp transverse stripes of the tiger, the circular broken spots of the leopard, the uniform colors of lions and pumas. Our little genets were also interesting in having their claws semi-retractile, that is, intermediate between the non-retractile claws of the ancient fossil carnivores and the fully retractile claws of the cat. Unfortunately, in spite of Dr. McGregor's kind, if forcible, ministrations of milk, they did not live long, but we carefully injected their bodies with preservative fluids so that

they will be valuable documents for future anatomical study.

Another curious carnivorous mammal at Tschibinda was a polecat (*Ictonyx zorilla*) belonging to the great family of the martins, weasels, ferrets, badgers and skunks The body was remarkably elongated and cylindrical between the shoulders and the hips. The head was also bluntly cylindrical, provided with short jaws and excessively strong shearing teeth. The limbs were short, stout and well-clawed. so that the animal seemed well able to pursue the digging rodents into their holes and kill and eat them. This mammal also belongs to a very ancient family which had many representatives in the fossil-bearing formations of Europe and North America. It affords another example of the faunal kinship of modern Africa to that of ancient Europe and Asia

Aside from a few small lizards the reptiles of Tschibinda were very inconspicuous, with the brilliant exception of the chameleon. These highly curious lizards might occasionally be seen clinging to the vines and branches by their clamp-like hands and feet, very slowly pulling themselves along with elbows and knees widely extended. They have the remarkable power of sneaking up on a resting fly, taking careful aim and then shooting out their enormously extensile tongues with inerrant accuracy, the sticky end of which hits the fly before it can spring into the air. The natives were evidently afraid of these perfectly harmless creatures. Chameleons may be regarded as relics of the Age of Dinosaurs because their ancestors were contemporaneous with the dinosaurs, as we know from certain fossil jaws and teeth.

The birds of Tschibinda were extremely numerous, at least in species. As I sat in my jungle studio they twittered and screeched and literally mocked me in my ignorance of this vast subject. My respect for the ornithologists increased daily as I found out how hard it was to identify any one type of screech with a particular bird, who would rarely "stay put" long enough for one to be sure which was which. I heard no bird songs that could compare in beauty with the songs of our thrushes, but many of the Africans wore brilliant plumage and made up in quantity of song what they lacked in quality. Perhaps the most brilliant bird I saw was one that presented a curious suggestion of a humming-bird, with its whirring wings, iri-

—Photograph by H. C. Raven

CHAMELEON.

—*Photograph by H. C. Raven*

NATIVES COVERING FRAMEWORK OF HUT WITH A THATCH OF PLANTAIN LEAVES

descent blue breast and scarlet throat band. Mr. Raven tells me that this was one of the sun-birds.

During much of our six weeks at Tschibinda McGregor and Engle took and developed a great many cinema and still photographs. They also had an accumulation of negatives from the earlier part of our journey and they felt that it was advisable to develop and fix the negatives in the field in order to protect them against the inroads of the damp and hot climate of the countries through which we were still to travel. Accordingly they had the natives build a temporary dark-room, in the manner described above. Many were the unexpected difficulties they encountered and ingenious were their methods of overcoming them, but to tell of all this would require a chapter by itself.

(*To be continued*)

THREE QUARTERS OF A CENTURY OF MEDICAL PROGRESS

By DAVID RIESMAN, M.D., Sc.D.
PROFESSOR OF THE HISTORY OF MEDICINE, UNIVERSITY OF PENNSYLVANIA

SEVENTY-FIVE years ago the status of medicine was not brilliant. Medicine had not yet fully emerged from the speculative era and lacked the foundation upon which to build a real science of medicine, namely, a knowledge of causes. Pasteur was at work, but his researches had not yet greatly fructified the medical field. Nevertheless, an industrious, reticent Scotch Quaker was thinking and a young German country doctor was also thinking along new lines. These men, Lister and Koch, with Pasteur, inaugurated the new era in which to this day we have our being. We are not content with a mere study of symptoms; we are not satisfied to classify diseases on superficial landmarks as was done by that medical Linné, Sauvages,[1] and by his followers. We look for causes and are rarely willing to call a disease an entity unless we have fathomed its cause, though not necessarily its specific cause. That rational attitude we owe to Pasteur and to Koch.

In the period with which we are concerned many causes of disease were discovered—anthrax, wound infection, the septicopyemia of older writers, cholera, tuberculosis, tetanus, meningitis, pneumonia, malaria, syphilis, African sleeping sickness and a number of others. In the first flush of enthusiasm created by these epoch-making discoveries the germ was raised to an all-important position as practically the sole factor in disease. But in recent times the older idea of constitution has again come into medical consciousness. The germ is necessary, but it can only grow if it falls on proper soil. While much nonsense is written about the soil—the human constitution—nonsense that is reminiscent of the notions of the phrenologists, Gall and Spurzheim, the subject is one of vital importance deserving careful study if we are to understand and to master infectious and other diseases.

In the time under review medicine more than ever has shown its catholicity. It has borrowed from the exact sciences all the discoveries that could help in the study and treatment of disease. The triumphs of chemistry have changed the practice of medicine in a way that was far beyond the dreams of Mendeléeff and Lothar Meyer, when in 1869 they announced their fertile generalization of the periodicity of the elements.

Chemistry has revealed to us facts of enormous importance about the composition of the blood. Blood chemical studies are now routine procedures. In my early days the blood was practically untouchable. We bled patients occasionally for the relief of shortness of breath, of cyanosis, in apoplexy, in uremia and eclampsia, but not for the purpose of ascertaining how much sugar, urea, calcium, phosphorus, etc., might be present. It was first necessary for the chemist to discover methods of making these tests without the necessity of abstracting too large amounts of blood. And, marvels of marvels, in recent times methods have been devised of making these tests with mere drops of blood. Blood cultures and Wassermann and agglutination tests, though of a different genre, may be mentioned in this place.

While organic chemistry may be said to have had its birth in 1828 when Woehler synthesized urea, its greatest triumphs

[1] Sauvages enumerates 2,400 different diseases arranged botanical-wise into classes, orders, genera and species.

fall largely in a more recent period. At first analytical, chemistry soon became synthetic, its magical activities resulting in the preparation of dyes and drugs and of substances which were supposed to be produced only in the laboratory of nature, like adrenalin and some of the vitamins Among the triumphs of chemistry is the discovery of hormones, the impetus for which was given by Bayliss and Starling in 1902 Not only are the hormones of great importance in nearly all vital processes, but they also show us with what minute quantities nature can work large results. That amazing little organ, the pituitary body, practically of no known significance in 1860, is capable of secreting at least eight different active substances,[2] among which those concerned in the sexual cycle are the most recently discovered. The discoveries are coming so rapidly that it is difficult to keep them in order in one's mind. How little we dreamt that the pituitary gland played so important a rôle in the sex life. Perhaps investigators are complicating the subject by postulating so many interacting hormones—nature, after all, may work more simply. The small parathyroid glands, which until 1880 were overlooked, are also marvelous; they control to a large extent the calcium metabolism of the body. The use of the hormones as therapeutic agents has been another tribute to the immense power of chemistry Collip's discovery of antihormones, while at first confusing the picture we had formed, may help us to explain a number of hidden facts.

To the triumphs of chemistry belongs chemotherapy, the synthetic production of powerful therapeutic agents with which the name of Paul Ehrlich is indissolubly connected That chemistry has also given us poisonous gases and powerful explosives is but another illustration of the Ormudz and Arhiman principle in human affairs.

Some of the great discoveries of chemistry do not seem to have an immediate application to medicine, but that does not prevent their possible usefulness in the future Heavy water containing hydrogen of atomic weight 2 and 3 may have biologic properties. It has forced us to give up the original idea of the immutability and unitary character of the chemical elements The 92 are now represented by about 250 isotopes, many of which may play a rôle in life's processes. The last sixty years have also witnessed the discovery of a number of elements previously missing from the periodic table, so that the list of the 92 is almost complete; and if the work of the young Italian physicist Fermi is substantiated, there may be 93 elements, perhaps more, these last comers being, however, artificially produced.

One other chemical triumph should be mentioned, namely, the discovery of vitamins. Their existence was first suggested in 1841 by Dr. G. Budd, an American physician, but his suggestion bore no fruit. Sir Gowland Hopkins, Mendel, Eijkman, Fraser and Stanton, Hess, McCollum, Mellanby, Chick, Windhaus, are some of the men and women to whom we owe knowledge of these subtle substances which in infinitesimal amounts exert their indispensable action on the body. One ten-thousandth of a milligram of calciferol added to an inadequate diet will sustain the life of a rat that would otherwise succumb on such a diet This is a further illustration of nature's sparing ways One might almost be inclined to think that these facts justify Samuel Hahnemann

The beneficial effects of sunlight on the human body, known from time immemorial, find their explanation, in part at least, in the power of the ultra-violet

[2] Dodds and Noble (*Nature*, May 11, 1935) have described a new substance obtained from the posterior lobe which is capable of inducing macrocytic anemia and gastric hemorrhage in rabbits.

rays to activate certain vitamins otherwise inactive.

The isolation and synthesis of various hormones and vitamins by laboratory workers has been a steady aid to therapeutic advance. It was only after the chemistry was known that the close chemical relationship of many of these vital substances was fully realized. They seem to be formed in nature, almost as if on some chemist's plan, out of the same molecular brickwork.

Practically within the last year it has been shown that substances no less important to the body than cholesterol, vitamin D, the female ovarian hormone, the male testicular hormone, the embryonic organizer hormone (on which Needham has done such startling work), the bile acids and the cardiac stimulants, such as digitalis, are compounds built around the phenanthrene nucleus. Phenanthrene and its isomer anthracene consist of three linked benzol rings and are common constituents of coal tar. Their interest for us until recently was chiefly as the chemical keystones of the dyestuff industry.

It was not long before an even more provocative discovery was made. By laborious processes of purification and analysis it was found that the potent cancer-producing substances in tar had the same structural foundation as this group of vitamins, hormones and bile-products. These researches make it both easy and attractive to think of cancer as some profound metabolic disturbance of cholesterol and bile acid chemistry.

Medicine has also made use of the advances of physics, the most important in this field being the X-ray. Perhaps this is the most important of all discoveries applied to medicine in modern times. I need not dwell upon the significance of Roentgen's discovery. In diagnosis it is indispensable; in treatment it is of great service. Since 1913 when its nature as a form of radiation was revealed, it has given us an insight into the atom and enabled Moseley to arrange the elements in regular order and to explain the mystery of the periodic table. The work of Laue, the Braggs and others with the X-ray has shown that nearly everything in nature is in the last analysis crystalline and every substance liquid or solid reveals to the X-ray the characteristic arrangements of its constituent atoms and molecules.

To the great discoveries in physics of which medicine makes use belongs that of radium by the Curies in 1898. In radium and in the X-ray we have two powerful therapeutic agents, the usefulness of which is destined to increase with time. The discovery of radium and of radioactive substances, some of which are now made artificially, has changed completely the course of physics—that science to-day speaks another language. We may confidently expect that some of its progress will redound to the advantage of medicine.

While the other fundamental discoveries of the physicists, the structure of the atom by Bohr, the mysterious constant of Planck—the quantum—the transmutation of the elements by Lord Rutherford, relativity by Einstein, and wave-mechanics are as yet of no immediate benefit to medicine, no one can say that they may not be. Witness the radio. The cosmic rays discovered by Wulf, Gockel, Hess and Kolhörster, and intensively studied in this country by Millikan, Compton, Swann, Johnson and others, seem to pass through us without our being aware of it. While the penetrating power of the cosmic ray is greater than that of any other radiation known, only a very few fall upon each individual day by day. Whether or not they produce any effect is beyond our present knowledge.

I shall now take up matters more strictly medical. When Meyer of Copenhagen made the discovery of the signifi-

cance of adenoids, he thereby laid the foundation not only of children's health but also of many medical fortunes.

I have spoken of the work of Pasteur, Lister and Koch. I need not dilate upon its transcendent importance for medicine and surgery. Although Ephraim McDowell performed the first ovariotomy in 1809, such operations were few and far between until the era of antisepsis. The first appendectomy in this country was done in 1864 by Willard Parker, but not until Reginald Fitz of Boston wrote his classical paper on "Perforation of the Appendix" did the operation of appendectomy, so life-saving and so profitable for the surgeon, come to be an everyday event.

But surgery has other triumphs. The gall bladder is no longer the *noli me tangere* that it was in the days of my youth. The Graham-Cole test of cholecystography has given to the operation a much surer basis than it had before.

Urology, formerly a minor and hardly respectable specialty, has in our time become an important scientific branch of surgery, the devotees of which have cause to be proud of what they have achieved in hardly more than a generation. Here, too, the X-ray has been of signal service as well as several special chemical tests discovered within the twentieth century.

From the end of the eighteenth century onward we find occasional suggestions in the literature that diseases might be conveyed by insects, but it remained for our own time to prove this with results beyond all expectations. Beginning with Manson's discovery in 1879 of the transmission of filariasis by the mosquito, we have that of Theobald Smith of the tick transmission of Texas fever of cattle, in 1892; three years later Ronald Ross discovered the malaria organism in the mosquito; in 1899 Reed, Carroll, Lazear and Agramonte demonstrated the mosquito transmission of yellow fever, the ulterior consequences of which were the Panama Canal and the disappearance of yellow fever from Central America and from the islands to the south.

The part played by the louse in typhus transmission so dramatically portrayed by Zinsser is a fact acquired at a somewhat later time. In a number of other diseases such transmission is suspected but not proved.

Viruses as a cause of disease were not known fifty years ago. They were discovered at the end of the nineteenth century. To the virus diseases belong smallpox, vaccinia, psittacosis, infantile paralysis, lethargic encephalitis, foot and mouth disease, also probably chickenpox, yellow fever and herpes, as well as a number of diseases of animals. There is still a good deal of discussion as to the nature of viruses. They are much smaller than bacteria—the virus of poliomyelitis is estimated at 10 mμ, which approximates the size of a protein molecule.[3]

The viruses are filtrable and with few exceptions are invisible with the microscope. So small are they that the question has arisen whether they are really organisms at all. Some believe that they originate in the host, but the best recent authorities are of the opinion that they are self-propagating microorganisms.

A filtrable agent in many respects resembling viruses of animal diseases is the bacteriophage discovered independently by Twort and by d'Herelle.

Great advances have been made in our knowledge of the physiology of muscle and nerve. Since Du Bois Reymond it had been customary to regard a nerve as a mere wire, passively transmitting electrical impulses to various organs and muscles. Its only intrinsic property was thought to be resistance to this current, as shown by a wire. Since the turn of the century the work of Parker, Hill, Gasser, Gerard and others has changed this notion completely. The nerve is not

[3] One mμ equals one millionth of a millimeter. The smallest bacteria have a diameter of 750 mμ.

passive, but has a very small but essential metabolic activity. It exhibits no resistance to impulses but indeed propagates these electrical waves itself. Dale and Cannon have amassed much evidence to show that these impulses act only indirectly on a muscle or gland, through the liberation of some chemical substances, acetylcholine and sympathin, at the site of the nerve endings. Accordingly, as the nerve fibers produce acetylcholine or adrenalin-like substances, Sir Henry Dale speaks of them as cholinergic and adrenergic.

Not only has the newer nerve physiology revealed electrical activities and chemical changes in nerves carrying impulses that were scarcely suspected a few years ago, but lately by ingenious apparatus electrical forces have been revealed in the living brain. It would appear as if all vital processes were in the last analysis electrical.

Cerebral localization has been greatly advanced since the days of Broca. This has led to earlier diagnosis of brain lesions and the more successful surgical treatment where such treatment is indicated.

A striking reversal in ideas has also occurred in our explanation of muscle contraction. The energy for muscle activity was produced, so our fathers thought, by the burning of sugar to lactic acid and carbon dioxide. Now we know that the energy of these reactions is produced as heat several seconds after the actual contraction is over. Where, then, does the energy come from which we can transform into muscular work? A large number of substances take part in the process. The following polysyllabic compounds have been found: Hexose diphosphoric and monophosphoric acids, glycerophosphoric acid, phosphoglyceric acid, adenylic acid, phosphoric and pyrophosphoric acids, phosphagen or creatine phosphoric acid, pyruvic acid, methyl glyoxal, glyceraldehyde, dihydroxyacetone, and the end is not yet.

Great advances have been made in our knowledge of the ductless glands; I have already mentioned the pituitary and the parathyroid. It is a revelation to read a text-book of to-day and compare its chapter on the ductless glands with one of fifty years ago. In the case of the thyroid, the adrenals, the pancreas and the sex glands, as well as in that of the pituitary and the parathyroid, our knowledge has been revolutionized. We have hypo-, hyper- and dysfunctioning with characteristic clinical pictures and we have methods of treatment that were not dreamt of fifty years ago. I would not deny that some enthusiasts are "a-babbling of green fields," justifying perhaps David Marine's saying that "endocrinology is endocriminology," but on the whole we are on solid ground.

From the point of view of public health several facts are of transcendent importance: Filtration of water, which has reduced and almost eliminated typhoid fever and the intestinal diseases of childhood; control of hookworm disease, of malaria, of pellagra and yellow fever. Nothing is more inspiring than the campaign against tuberculosis. In the case of typhoid fever and diphtheria, vaccination, immunization and the Schick test have added themselves to the general hygienic measures to reduce these diseases almost, if not quite, to the vanishing point.

The health of the school child has become the concern of the community. Prenatal care likewise is an advance that has come within the memory of men now living. It seems that we have advanced immensely in everything that concerns the protection and prolongation of human life, except in our political economy and in the abolition of war. The political doctors in control of our national health up to a recent time have neither correctly diagnosed nor adequately treated the sick body-politic. Nor have these same statesmen used preventive measures they might well borrow from medicine for the prevention of war.

The Spanish-American war brought in

its train a terrible epidemic of typhoid fever but also and as a consequence a totally altered status of the army doctor. Line officers who had looked with contempt upon the "Saw Bones" of the Army realized that the modern doctor knew more of sanitary science than the general, and that by accepting his advice the health of the army would be preserved. This change in attitude was certainly noticeable in the great war.

In treatment the advances have also been breath-taking. I have alluded to antitoxins; many coal-tar products have been discovered that are useful in relieving pain—we can scarcely do without them. We have salvarsan and other chemotherapeutic agents, insulin for diabetes, and liver therapy in pernicious anemia, a disease that until 1926 had proved invariably fatal. It would appear that the active principle or principles upon which the efficacy of liver depends will soon be isolated—another triumph of modern chemistry.

Blood transfusion should be mentioned in this connection. It is an old method, but it fell into disuse because of its dangers. But since Landsteiner's fundamental discovery of blood groups and through a number of technical advances, the dangers have been so minimized that blood transfusions are daily occurrences in large hospitals.

One of the most important contributions to scientific treatment is the concept of focal infection. While there are obscure references to the subject in the writings of the French surgeon Petit and in those of our own Benjamin Rush, it was not until Frank Billings and Edward C. Rosenow developed the idea that it became part of medical consciousness. It must be admitted that millions of sound teeth have been sacrificed on the altar of focal infection and many other unnecessary operations and procedures have been done, but that does not lessen the value of this great American contribution to medical practice.

There is one therapeutic advance which came about so gradually, so undramatically, that it might easily be overlooked. It is the disappearance of the nauseous polypharmacy that had been bequeathed to us by the Middle Ages. To be just I must give credit for this largely to the disciples of Samuel Hahnemann. Homeopathy has had a totally negligible share in the progress of scientific medicine, but the palatability of its drugs, whatever their actual efficacy, has greatly influenced the art of prescribing of the regular profession.

Technical advances are legion and have redounded to the special advantage of medical diagnosis and of surgery. There are, for example, the methods of removing foreign bodies from the air passages, means for the inspection of internal cavities, the blood pressure apparatus, the electro-cardiograph, the basal metabolism apparatus and many others.

The study of reflexes, which is of incalculable value in the diagnosis of nervous diseases, is also something that has come into use in the last half century.

Advances that can scarcely be overestimated have been made in anesthesia. In my early days the anesthesia was nearly as dangerous as the operation itself. Now all that is changed. In addition to ether and chloroform, the latter rarely used in this country, we have new chemical anesthetics as well as gas anesthesia, spinal anesthesia, local anesthesia with cocaine and its derivatives, and infiltration anesthesia, which since it was first proposed by Schleich in 1890 has come into greater and greater use.

Unfortunately there remain a number of diseases that are as recalcitrant to treatment as ever—leukemia, multiple sclerosis, paralysis agitans, cancer of internal organs and Hodgkin's disease.

I am not sure whether the addition of new disease can be considered an advance. Nevertheless, the recognition of such diseases is creditable to medicine.

It is not necessary to mention all the diseases that have been added to our nosology in the last 75 years. I shall name only a few—Vincent's angina, trench fever, infectious jaundice, paratyphoid fever, botulism, undulant and abortus fever, lethargic encephalitis, tularemia, psittacosis, pneumoconiosis, agranulocytosis, infectious mononucleosis, coccidioides granuloma and acromegaly.

Psychiatry or the study of diseases of the mind was one of the last branches of medicine to feel the fructifying effects of modern science. Living in a cloistered atmosphere the psychiatrist was concerned mainly with classifying mental diseases and administering such meager treatment as he knew. On the outside, *fuori le mura,* men were busily studying the mind by new methods, and these methods have done more to clarify the activities both of the normal and of the diseased mind than all the studies since the days of Benjamin Rush, the first American to concern himself with mental aberrations. The work of Freud, Jung, Adler, Alexander, whatever one may think of its therapeutic value, is beyond doubt of enormous significance for the understanding of the normal and the abnormal human psyche. And the terminology created by psychoanalysis —complexes, inhibitions, frustrations, superego, sublimation—has become an integral part of all civilized languages. General literature has absorbed the newer ideas and industry has applied them to its workmen, the army to its soldiers, and colleges to their students.

Perhaps the greatest advances of all have been in the domain of medical education. The extension from a two years' course or the apprentice system to a three years' course and eventually to a four years' course, the disappearance of proprietary schools run for profit, the internship, the laboratory, state boards of examiners—all these advances have been of immeasurable benefit to medicine and to the public weal. Belonging to the same category are the great research institutions of which the Rockefeller Institute for Medical Research is an example. The Mayo Clinic, a typical American product and deserving to rank as the eighth wonder of the world, has also been an important factor in medical education.

In the education of medical men the medical journal occupies a prominent place. There are too many journals, but on the whole that is a lesser fault than too few. The American Medical Association and its *Journal* have been important factors in improving medical schools and in educating students and physicians.

I have one complaint to make with regard to medical education—it takes too long. I do not mean to say that the medical course itself is too long or that the one or two years' internship should be shortened or abandoned; it is the premedical course that takes too long. At the present time a student rarely enters the practice of medicine before he is twenty-eight or twenty-nine years of age and it takes a few years thereafter for him to make a livelihood. This imposes a great burden upon the parents. The principal way of shortening this is to speed up primary and secondary and college education. The study of medicine should be begun at not later than twenty—Laënnec began at fourteen and a half years. There is no reason why the college course could not be shortened to three years, and the high-school course also.

I can not refrain from saying a word about the full-time system of clinical teaching, the introduction of which into medical education we owe to Abraham Flexner and the late William H. Welch. The ideal underlying this plan is certainly correct, namely, that the teachers of medicine should give a large part of their time to the job of teaching. When many of us were in medical schools, the professor of medicine and the professor

of surgery were busy practitioners and had little time for their pedagogical duties. It is a question, however, whether the extreme academic method advocated by some educators is the best. At any rate, there should be on every faculty a group of clinical teachers who are practicing extramurally and can bring to the student a point of view that no intramural teacher can bring. Such clinical teachers should have proper faculty standing and academic honors as well as salaries commensurate with their abilities. Such men whom we might call part-time teachers are necessary if the student is to get a complete picture of medical practice.

Trained nursing belongs to the advances of medicine. Trained nursing had its origin in Germany, was improved in England and perfected in this country, where it began but little over fifty years ago, yet it has achieved triumphs beyond all expectations. No one can dispute the statement that the American trained nurse has no peer anywhere in the world.

Social service is also a medical advance belonging to our time. It is an indispensable adjunct to medical treatment in hospitals and out-patient departments.

Besides the trained nurse and the social worker there is a third female adjunct to medical practice that did not exist in the last century, namely, the technician. If it were not for her the time-consuming laboratory studies that are now so universally made would not be possible, for the doctors never could find time to do them. Furthermore, much of the research work would be hampered if there were not technicians to do the simpler things.

Seventy-five years ago there were two branches of medical practice—medicine and surgery. The surgeon did everything that could be done with the knife and the medical man did everything else. Both did obstetrics and the surgeon usually also practiced medicine. The first specialist probably was the ophthalmologist and he was looked down upon as being unethical. What a change has come over the picture. Medicine is split up into almost countless specialties, each one organized into a closed society, each one with journals and text-books of its own, each one thinking that it is the most important branch of medicine, and each more and more ignoring every other department of the healing art. While in a sense such splitting up is regrettable in that it narrows medical practitioners, nevertheless it has resulted in great advances. The most recent split-ups are cardiology, allergy and angiology or diseases of the blood vessels. None of them is really a specialty; it should be undertsood by every practicing physician, but because men have devoted themselves exclusively to them, advances have been made that could not well have been made otherwise. The analytical process, I believe, will go on, for synthesis is not possible, the individual fields are too vast.

A subject that is probably as old as the practice of medicine itself is that of medical economics. Yet at no time in history has it occupied so prominent a place either in medical consciousness or in the lay mind as now. Should I include it among the advances of medicine? The answer depends on our point of view, whether we are social-minded or individualistic in our *Weltanschauung*. It would carry me too far afield if I were to discuss this subject, which seems to have divided the medical profession as states rights and slavery divided our nation seventy-five years ago. Perhaps it will require something like a civil war—of words and ideas—to settle the question, and when settled the outcome may perhaps be ranked by future historians among the greatest advances of all in medicine.

AUDITORY PERSPECTIVE

By JOHN MILLS

BELL TELEPHONE LABORATORIES, NEW YORK, N. Y.

PERHAPS you are reading this article by artificial light. Even under the best of conditions light is not uniformly distributed and areas equally distant from the source are not equally illuminated. A quick glance around a room will tell whether or not that is so. In the sweep of the eye a comparison is made of the brightness of similar surfaces. So natural is such a judgment that if one picks up a book in an irregularly lighted room he instinctively turns or moves to a position of more adequate illumination.

An ocular comparison of this character is possible only when the intensity of the radiation from the lamp remains constant during the series of observations. You can not be sure that one corner of a room is darker than another if, while you turn from one to the other, the light source changes in brilliancy. It is also necessary for accurate judgment that the surfaces which are compared shall be similar in texture and color and in the angle at which they reflect to the observer.

Instead of light let there be a source of sound. It is now impossible from a single position to draw any conclusion whatever as to the distribution of the sound. The only way a comparison can be made is by placing one's ear successively at the locations which are to be compared. Since this is awkward and a human ear is not a good measuring instrument for a series of determinations of acoustic power, it is usual to employ an electrical ear. A microphone can be mounted on an arm, or boom, to swing around the source of sound; and the current can be recorded continuously as its position changes. In that way the sound intensity can be obtained for each angular degree around the circle.

Such data are presented most conveniently in what is known as a polar plot. On a sheet of paper place a dot and radially from it draw lines in every direction. Give to each line a length proportional to the intensity of the sound in that direction. Usually the interest is in only half the possible directions, namely, those within 90 degrees on either side of the direction in which the sound source faces. If it radiates uniformly over this 180 degrees the plot will be half of a circle; but generally the graph resembles a leaf of a plant, as does that for the sound from a violin.

If a blindfolded and one-eared listener were swung slowly around a semicircle with a violinist at its center he would probably insist that he was being moved back and forth from the source. Without eyes to aid and without the ability to judge direction which is the important phenomenon of binaural audition, changes in intensity must be associated with changes of distance. When this hypothetical listener is in the position to face directly the violin—not the violinist—the sound he receives may be eight or ten times as intense as that he will receive in most of the other possible positions.

Imagine the violinist to face a battery of microphones, so arranged that their combined output is always the maximum power of his instrument, regardless of his changing position. Now translate the current through a loudspeaker which will distribute the sound with practical uniformity in all directions. No one in the audience of the loudspeaker is then subjected to partiality; and all hear exactly what the violinist plays. A properly designed loudspeaker can distribute music through a hall so that the direct sound is the same for all listeners at the

same distance from the speaker. There would be obvious box-office advantages to a system which could deliver to all seats alike; but there is another aspect to be considered.

What a loudspeaker can deliver so impartially must first be collected by a microphone. This electrical ear picks up the same sound as would a one-eared listener in its place. When the source of sound is a soloist, microphone and monaural listener are at no disadvantage as compared to a binaural observer. This is true also, of course, whenever the music arises from a group of sources, as for example a band, provided it is far enough away. For an orchestra in an ordinary auditorium, where the instruments are distributed throughout a considerable angle, the binaural listener has the advantage. He can detect the direction of the individual sources.

Aural localization of the direction from which a sound comes has its physical basis in the different effects which the wave produces in the two ears. One of the obvious differences, but one usually of least importance, is in the time of arrival of the wave at the opposite ears. When one hears a short sharp sound, like a tick or click, he tends instinctively to turn toward the side on which it was heard first.

Another difference, which is particularly important when the sound is complex, is that of quality. The high-frequency components of a sound are propagated in short waves. For example, at ordinary room temperature the wave-length of a pure tone of 1,134 cycles is one foot; of 2,268 cycles, six inches, which is about the shortest distance between ears, and of 8,000 cycles, a component of some speech sibilants, only one and three quarter inches. Whether or not a wave train casts a sharp shadow depends upon the size of the obstacle as compared to the wave-length. Just as a pin point will form a shadow to a light, so objects as small as the human features will shade from a radiation of high-pitched sound. Listen to speech with one ear and notice how much more pronounced are the consonantal sounds when the speaker faces the ear and the short waves have direct access to the canal. Because of such effects, when one listens binaurally to complex sounds from elsewhere than directly ahead, or behind, the overtone quality is bound to be different at the two ears.

For the middle range of audible frequencies, for which the wave-lengths are larger and the shielding can never be complete, the head itself will shield enough to make appreciable difference in loudness at the two ears. Imagine an observer, with his left ear plugged, while a source of steady sound swings around his right side from directly in front to exactly behind. The loudness increases until the source is almost opposite the right ear; then drops; about three quarters of the way around it falls slightly below the value it had when the source was straight ahead. When the experiment is tried by stopping the right ear instead of the left, but moving the source as before, the loudness decreases more rapidly because the head then acts as a shield. It reaches a minimum when the source is about opposite the right ear and gradually increases, ending at the same value as it did for the right ear.

In binaural hearing each ear functions as just described. The more nearly the sound is directed into one ear, the louder it seems to that ear and more than equally weaker to the other. For speech the difference in intensity may correspond[1] to a power ratio of ten to one.

When the sound is of low frequency, and is not rich in overtones on the basis of which quality differences may be perceived, its wave-length is so large as compared to the human head that there is no shielding and no appreciable difference

[1] For more complete data see the chapter entitled "Plots and Graphs" in "A Fugue in Cycles and Bels."

in loudness. This is particularly true for pure tones below about middle C. In that case the source cannot be located by unaided ears. The sound lacks direction and seems to pervade the surrounding space.

Localization, however, is possible by utilizing a pair of electrical ears with greater separation than is human. Two microphones may be mounted at opposite ends of a long rod, arranged to swing on a pivot at its center. The microphones connect respectively to right and left head-receivers. In the simplest case, the rod with its electrical ears is turned until to the listener the sound seems directly ahead; then the line connecting the microphones will be at right angles to the direction of the sound. This fundamental principle was employed in the world war in the location of airplanes in flight. There is no shielding, however, and the localization is due to the difference in time of arrival of the successive condensations at the two electrical ears. There is, in other words, a difference of phase at the two microphones when the sound arrives obliquely.

Human ears, when sight or the sense of touch also do not supply evidence, can be completely fooled as to direction.[2] Imagine a small stage on which, RU and LU, are two loudspeakers concealed by a front drop. The listener occupies a center seat a few rows back. Current for the speakers comes from a single microphone offstage, but the output of each speaker is separately controlled. A solo artist is before the microphone and the loudspeakers are set for equal volumes. To the listener the soloist is unmistakably just behind the center of the curtain. Next, the output of one speaker is gradually increased, while the other is decreased. The artist apparently is moving behind the curtain toward the more intense speaker. A net difference of about 12 decibels[3] between loudspeakers will walk him to one side of the stage; and then 24 in the opposite direction will move him to the opposite side.

A more flexible arrangement is obtained when the two loudspeakers are supplied by independent microphones. A portion of the offstage room is then laid out as a miniature or studio stage. On a line in front of this stage, and widely separated, are mounted the microphones. The outputs of the loudspeakers correspond respectively to what the microphones pick up. If a performer on the miniature stage is nearer one microphone than the other, to the listener he will have an acoustical image which will occupy a corresponding position on the curtained stage. As he moves, and so changes the relative proportions which the microphones receive of his acoustic output, his image will move correspondingly. All sounds on the studio stage are thus reproduced in their spatial relationships.

Through the application of this principle of binaural audition, and by the utilization of high-quality microphones and loudspeakers, it is possible to reproduce with essential illusion an orchestral performance. Somewhat better illusion, as to location front and back, is obtained when three channels are used instead of the two just described. In that case there is provided for the miniature stage a third and centrally placed microphone which is connected to a loudspeaker midway between the other two. This third channel is also particularly advantageous when vocal soloists are to be accompanied by an orchestra.

It was this three-channel system which was used in the first demonstration of transmission and reproduction in auditory perspective. That took place on

[2] An early illustration was "Oscar" in the Bell System exhibit at the 1933 Exposition in Chicago, which is described in the chapter on "Extensions of the Senses" in "Signals and Speech in Electrical Communication."

[3] That means making the sound from one loudspeaker about 16 times as intense as that from the other.

April 27, 1933, under the auspices of the National Academy of Sciences, before whom at an earlier meeting there had been presented a technical discussion of the method and equipment. The demonstration marked the conclusion of a series of telephonic researches in which Dr. Leopold Stokowski and the Philadelphia Orchestra had generously assisted. In Constitution Hall in Washington a large audience of music lovers and scientists listened to the reproduction of a program rendered by the orchestra in Philadelphia under the leadership of Associate Conductor Alexander Smallens. Transmission between microphone and loudspeaker was over specially arranged telephone lines. The electro-acoustical system was demonstrated later at Philadelphia, with the orchestra playing in an offstage room; and still later in New York City before various engineering societies, with another and smaller orchestra.

The original demonstration was certainly an historic occasion from the view-point either of music or of electrical communication. Although it was a complete presentation of the new instrumentalities which science had made available to musicians, the emphasis was not upon how the electrons went around but upon the heights to which they could carry a listener. Representative selections from Bach, Beethoven, Debussy and Wagner were interpreted by Dr. Stokowski. For that purpose the dial controls of the electrical equipment were located in a first-row box at the rear of Constitution Hall, from which point he conditioned the music of the distant orchestra to bring it into accord with his own ideal. From the scientific standpoint, however, from which the system must be considered if its potentialities are to be appreciated, the demonstration was not single featured; instead it presented a number of aspects.

First of importance was the fact that the equipment and transmission facilities of each channel picked up, transmitted and reproduced all the musical sound presented to its microphone which an ordinary human ear could perceive. All components of the music within the range from 40 to 15,000 cycles were faithfully reproduced. Further, there was no compression of the volume range; there was reproduced the full intensity range of the orchestra, a total of 70 decibels, representing for power of *ff* as compared to that of *pp* a ratio of 10,000,000 to 1.

Of similar importance was the arrangement and utilization of three channels whereby the reproduced music was presented in auditory perspective. Not only did this create an illusion, because the instrumental sounds seemed to arise from their usual orchestral positions on the stage, but more importantly it provided the same spreading of music throughout the hall as would have been produced if the orchestra had been present. In that way the "stereophonic" system recreated an atmosphere of sound not perceptibly different from that of a local orchestra. Without that atmosphere, which previous methods of electrical reproduction were unable to provide, music is one dimensional and lacks its true spatial relationships; it lacks in richness and texture.

Through the multichannel system of microphones, lines, amplifiers and loudspeakers, properly disposed according to the principle of auditory perspective and binaural audition, there may be reproduced in one auditorium all that ear could perceive of the music which occurs in a distant auditorium. In addition, however, the electrical system was developed and arranged to provide three extensions of music, carrying it beyond its inherent limitations and making possible new artistic effects. These three aspects of the demonstration were completely under the control of Dr. Stokowski, who was thus able to produce according to his imagination tonal effects and

intensities beyond previous human possibilities, but not necessarily beyond the dreams of composers like Wagner.

The relative importance of these extensions, artistically, may well be a matter of debate. To the present writer, who can justify his choice only on the non-artistic basis "I know what I like," it is enough to have heard the finale of Götterdammerung played at full power under Dr. Stokowski's direction; and rising above its most stupendous crescendos, the liquid notes of an unstrained solo voice! The soloist can sing to the central microphone while the other two pick up the orchestra for stereophonic reproduction; and the intensity level of the solo channel can be raised to bring the vocal portion into any desired relationship.

It may well be that the increase of intensity range will ultimately prove to be the extension of greatest importance. Not only can the equipment handle the full 70 decibels range of a large orchestra, but it can transmit and reproduce without overloading, and its consequent distortion, a range of 100 decibels. Allowing 10 decibels for the masking of sound by audience noise, this means practically full use of the hearing range of the human ear. Because the equipment can provide and tolerate about 20 decibels more amplification than is needed to reproduce the loudest orchestral music at its original intensity, it becomes possible for a director who controls its dials to increase his orchestra a hundred times. By the turn of a handle he can make its output that of a hundred times as many instruments, but all in the relatively small space required for a normal orchestra. He can also produce musical sounds very close indeed to the threshold of pain!

The last of the three extensions is accomplished by the introduction into the transmission system, between microphone and loudspeaker, of networks designed to discriminate against certain pitches. Dials then provide the director with a tapering control for the relative intensities of the components in the music. When he so desires he can enhance all the lower harmonics, emphasizing them the more the lower their frequencies. Or he may minimize their sounds to an equal degree. For the high-frequency components several steps of control were provided, permitting them to be discriminated against with greater severity. In that way thin tones may be eliminated and an unnatural color given to the music. If the high frequencies are reduced while the low are increased a maximum effect is produced.

What the final judgments on these effects will be, no one knows. Music and art must move slowly, for they are deeply rooted in the emotions and traditions.

These controls can, of course, be applied equally well to music other than orchestral, for example, to choir or chorus. Antiphonal effects can be enhanced or imitated by variations of the relative intensities of the right and left channels. Groups of instruments can be emphasized through the central microphone and loudspeaker. And all these, and other effects as yet untried, can be superimposed upon music completely reproduced in all its spatial relationships. The moment—and that moment occurred in the spring of 1933—when it became possible electrically to reproduce all the sounds of orchestral music, there was passed the boundary between natural and electrical music. For better or for worse, we are entering an important new period in the development of music.

THE LOST ART OF HARDENING COPPER

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DOWN the centuries from dim and distant days come strange, enchanting legends. Many of them are indeed well worth repeating, some of them continue to exert a rather surprising influence, all of them should be favored with a kindly skepticism. *Cum grano salis* is still an excellent prescription.

It is a human characteristic to treasure the traditions of a Golden Age of the long ago. There are tales which tell of happy lands now lost beneath the sea. There were men who lived long and robust lives. There were crafts and skills that can no more be attained. There were methods of working with materials and feats of engineering which still defy complete explanation. There were giants in those days.

If we could but find the keys to those precious secrets of the past—if we could but regain a knowledge of those long lost arts—what fame and fortune might not be ours?

It was in the year 1838 that an American orator of some note, Wendell Phillips, first delivered his now famous lecture on the "Lost Arts." This colorful discourse was accorded such a hearty reception that it came to be repeated over two thousand times during the succeeding forty-five years. It made a profound impression upon audiences of the Victorian Era. Many of the amazing modern applications of new ideas developing in the fundamental sciences were just around the corner, yet unsuspected by a world they were so soon to transform. It was still possible to thrill lyceum gatherings with tales of ancient miracles, many of which, even if true, would seem rather tame to twentieth century schoolboys.

There were, of course, some real wonders in that ancient world. Certain very remarkable skills were developed in more than one field of human endeavor. The evidence may be found not only in historical documents, but also in actual material objects which have survived the centuries. The great Pyramids of Egypt are obvious and trite examples. Even in times now considered ancient, they served as specimens of past glories. Travelers in the days of Alexander and tourists in a world ruled by the Caesars had a thoroughly modern attitude towards the old Pyramids. In the manner peculiar to sightseers, they came, they saw and left their marks on the already aged stones.

There are fragmentary records which contain allusions to many another great wonder of olden times. It is possible, however, by a careless or inaccurate translation of certain vague passages, to arrive at some quite absurd conclusions. Wendell Phillips applied his own unique interpretations, with most interesting results.

The popular lecturer apparently expected to be taken seriously when he spoke of the steam engines and railroads of ancient Egypt, when he declared that it was the custom of Nero to view the arena through an opera-glass, when he inferred that the Temple of Solomon was equipped with lightning-rods.

According to Mr. Phillips, it was not only in the scientific fields that everything had been worked out by men of bygone ages. Centuries ago every possible social problem had been talked into

rags by the parlor pinks of old Alexandria. And no doubt the lecturer was uncomfortably near the truth when he asserted that all jokes could be traced back to the wits of Athens.

Regarding one of the revered sciences, Mr. Phillips is quoted as remarking that "The Chemistry of the most ancient period had reached a point which we have never even approached, and which we are in a vain attempt to reach today." One is told that modern dyes can not begin to compare with those of olden times either in quality or variety. Steel swords were tempered to sever the finest threads and to fit into their scabbards like corkscrews. It is reported that the first travelers in Africa found a tribe in the interior with whom they traded razors, receiving in exchange metal blades the like of which had not been seen in so-called civilized countries. The tale is told of the Hindoo maiden who wore seven suits of muslin which were of so thin a texture that her father was moved to remonstrate with her for going about unclothed. Strange stories from many lands!

Glass that was discovered by accident while sailors sat around their fire on the seashore. Glass that was so flexible that if supported by one end, it would by its own weight dwindle down to a fine thread, so that it could be curved around the wrist. Glass that was really transparent and hard, but not brittle. Glass that when dashed upon a marble floor was bruised, but not broken. Glass that was pliable and could be re-shaped with a hammer.

As with the stories about the "universal solvent," certain very obvious and awkward questions must have occurred to discriminating auditors of the unbreakable glass fables. It was customary, however, to anticipate some of the objections and to squelch them with an explanation that was deemed quite unassailable. It appears that a crafty Caesar had the inventor put to death and threw all the malleable glass articles into the Tiber—thus the wonderful secret was lost.

Some curious references to very minute carvings and writings offered starting points for still other remarkable deductions. A complete copy of the Iliad was said to have been written on a skin so small that it could be contained in a nutshell (the variety of nut was not specified). From this and stories of like nature, Mr. Phillips concluded that the ancients possessed magnifying instruments and even had some knowledge of photography. In somewhat the same manner, it was argued that the old pirate, Mauritius, had a marine telescope, because of the reports that he was able to see ships far out at sea.

A frequently quoted tribute to the craftsmen of olden times is that their mortar outlasted the stones it cemented. However that may be, they did indeed build better than they knew. Long after the mortar and the stones alike have crumbled into dust, the traditions of ancient glories will be the living residues.

Among the legends which continue to exert their peculiar fascination are those which tell of the lost art of hardening and tempering copper. From a verse in the fourth chapter of Genesis to page one of this morning's newspaper, there have been rumors of priceless secrets about the red metal. Tucked away among the "begats" one may find the phrase that relates how Tubal Cain was "an instructor of every artificier in brass," which has suggested that he had some knowledge of the magic method. Newspaper columns of recent years prove that carefully prepared explanations, no matter how authoritative, can not dampen the enthusiasm of latter-day seekers.

The search goes on—a quest for the long lost art that made the metal of Venus supreme in the ancient world.

Old mythologies relate that when the goddess of love and beauty rose from the sea on the shore of the Isle of Cyprus, a looking-glass made of burnished copper served as her mirror. Whatever the explanation, certain ideas regarding Venus and mirrors, Cyprus and copper, came to be associated in the mystic sign of a circle and a cross. The name given to the red metal by the Romans derives from the beautiful island on which it was mined and the old Latin word passed, with slight modifications, into modern languages. For the Egyptians the ancient Ankh symbol had yet another significance which was most appropriate in relation to copper. It was the token of an enduring life.

The museums of the world house a vast collection of ancient articles made of copper and its alloys. Time has been kinder to this metal than to the less durable one which eventually supplanted it.

Thus it is that copper relics of every sort have survived—daggers and dishes, needles and necklets, rivets and rings, scissors and swords, tweezers and toys—almost everything imaginable, and some things of which the precise meaning is in doubt. There is, for example, the celebrated set of four sharp-bladed implements, held together by a ring and incased in a funnel-like protector of metallic copper. This Babylonian curiosity has been described variously as a group of surgical instruments, as an assortment of engraver's tools and as a manicure set.

In the Mediterranean countries the Ages of Copper and of Bronze were passing in the early days of Rome, but in some parts of the world they have persisted until recent times. Various factors relative to the natural occurrences of metals have always had the greatest influence upon their exploitation. It seems reasonable to assume, therefore, that most primitive peoples became acquainted first with the so-called noble metals—copper, silver and gold.

Occurrences of these elements in the simple metallic form are not as rare as might be supposed and they are, in small amounts at least, rather widely distributed over the surface of the earth. It becomes increasingly difficult to find them and one is inclined to underestimate the sources available to ancient peoples. Long ago most of the easily discovered grains, the more accessible ores, the readily mined deposits, were all cashed in.

In the older civilizations there came a time when bits of metallic copper began to be hard to find. Fortunately, it was not necessary to devise elaborate furnaces in order to reduce the ores of this metal. Many complicated theories have been advanced to explain the origin of smelting processes. The chances are that the methods resulted from observations of accidental preparations. Moreover, it should be recognized that the accident must have been an event which had a high degree of probability. It must have been an accident which many individuals had an opportunity to observe before its immense importance was fully realized. These considerations count against, for example, the theory that the process had its origin in the dropping of a piece of malachite paste, used by Egyptian ladies as a cosmetic, in the charcoal fire of a brazier.

The suggestions of the late William Gowland, of the Royal School of Mines, have been most generally accepted. There seem to be good reasons for believing that the camp-fire was the first primitive smelter. Whenever the ring of stones about a fire contained metallic compounds, or the fire was built upon an outcrop of metal-bearing rock, conditions were favorable for a reduction process. Puzzling over bits of metal found in the ashes, some one happened to suspect the connection between them and proceeded to perform a few simple

experiments. The formation of a shallow cavity to receive the molten metal was an obvious improvement and, as it was deepened, the familiar shape of a metallurgical furnace began to emerge.

The use of the copper carbonate, malachite, by the ladies of Egypt probably did have something to do with the operation of the world's oldest copper mines. Apparently they were worked for their malachite and turquoise by the great Pharaohs, possibly as early as 5000 B.C. The mines were located in the wilderness of a little peninsula destined to be made famous by a people who wandered around in it for forty years.

In an age dominated by the red metal, mining activities spread around the Mediterranean, from the mountainous wilderness of Sinai to the Isle of Cyprus and the Rio Tinto of Spain.

With the development of methods for extracting copper from its compounds and with the discovery of large deposits of its ores, the use of this metal expanded rapidly among the artisans of olden times. The properties of copper were, of course, of the greatest importance in determining the significant part it played in the rise of most early civilizations.

The outstanding chemical characteristic of the noble metals, copper, silver and gold, is their resistance to corrosion, which guarantees a long life and enduring beauty to objects into which they are fabricated. In their physical properties these metals exhibit something of a paradox. They are all comparatively soft, but also very tough and tenacious. Thus they excel all other metals in ductility, the property involved in drawing them into fine wires, and in malleability, the property which permits them to be rolled into thin sheets. These qualities are most admirable for many modern purposes, but the ancients were not interested, for instance, in the stringing of telephone wires.

Efficient tools were a vital concern in the lives of early peoples. Instruments were needed which combined toughness with hardness—hardness in cutting or abrasive action on other objects. It was a combination that was not easy to find. In ordinary cutting operations hardness was the prime requirement and many natural abrasives came to be used. Flints and quartzites were hard, but also were brittle and easily broken. The diamond is a familiar example of extreme hardness accompanied by a distressing brittleness, and rubber exemplifies how softness may be allied with unusual toughness. It was to metals that men turned in an effort to secure the best combination of those highly desirable attributes—toughness and hardness.

Copper could not assume its important place in the arts and crafts of ancient peoples until methods of hardening it were discovered. In the smelting of copper ores and in the fashioning of copper objects, it was inevitable that certain favorable conditions were noted and remembered. During some prehistoric period the problem was solved to a degree that was more or less satisfactory. There were and are two general methods by which copper was long ago and still may be hardened.

Mechanical working of copper notably increases its hardness. In shaping bits of metal into a desired form, the ancients did so by a process of hammering. This operation naturally produced a hardening, and it is likely that the renowned secret of Tubal Cain was not so much in his head as in his strong right arm. Spear-heads, daggers, arrow-heads, chisels, drills, knives and all implements demanding a sharp edge or point for cutting or piercing other objects, were hammered into shape and along the edge or point there resulted an excessive hardness, because of this prolonged cold-working. Many old relics have revealed this condition upon close examination.

As previously noted, an increase in

hardness is likely to be attended by an increase in brittleness, and this is especially true of copper hardened by excessive hammering or cold-working. Probably in some entirely accidental manner it was discovered that this overstrained state could be partially relieved by a reheating of the metal, and a primitive sort of annealing may have become a common practice.

Possibly even in olden times a certain amount of heat treatment, followed by quenching in water and other liquids, also came into general use. To such processes the word tempering has been rather loosely applied. This term should not, however, be confused with hardening, because the so-called tempering of copper may involve a softening of the metal. Nevertheless, the words hardening and tempering often appear interchangeably in the claims of modern rediscoverers of the lost secret.

The second general method of hardening copper was based on the fact that only the very pure metal is really soft. Almost any impurity that might have gotten into an ancient copper would have hardened it. The oxide of copper is particularly effective in this respect and in the first smelters, copper oxide had a good chance to get into the metal product. Once more the old familiar difficulty interferes. Many inventors have had their hopes raised high upon securing a copper which was undeniably hard, but which contained so much oxide that it was as brittle as glass.

There are elements which do increase the hardness of copper without intensifying the brittleness. Probably the first satisfactory combination produced was the alloy known as bronze and it was superior to ordinary copper in so many ways that an Age of Bronze gradually evolved. A simple bronze alloy is a union of copper and tin, and once again it seems likely that it was a freak of fate, the smelting together of ores containing both elements, that produced this new advance. An alloy of copper and zinc, which came to be called brass, was the product of another fortunate mixture. The historians of those early times so confused the terms applied to copper, bronze and brass, that it is now almost impossible in many cases to tell precisely which one the author had in mind. At any rate, for many generations copper, by itself or in combination with other elements, was the key metal in all the great states then rising to power. It was not until the advantageous qualities of iron and its alloys were fully realized that another inevitable change came to pass.

Copper did not yield its place without a struggle. The change came about ever so gradually, and there were countless individuals in those forgotten days who never really got accustomed to the newfangled instruments. There were many who stood firm in their belief that the old ways were best.

The most stubborn resistance to the new deal in metals was displayed among those who conducted religious ceremonies. It is recorded that by the old Roman Law of Numa there were numerous restrictions upon the use of iron in any sacred relation. The garments of the priestly *flamines* were fastened with bronze brooches and they were directed to have their hair cut with bronze scissors, being expressly forbidden to employ instruments made of iron. In founding their cities, a furrow was traced with a bronze ploughshare. Bronze sickles were used to cut magical herbs. Tools brought into holy places to cut inscriptions had to be made of bronze.

As it came to be recognized that iron was much more efficient than bronze for cutting inscriptions, as shown by experiments in non-holy places, some concessions became necessary. For a time it was permissible to bring iron tools into holy places, provided an expiatory sacri-

fice accompanied them. Before long the practice had to be winked at and finally ignored altogether.

The point has been elaborated in some detail because it suggests the nature of the flaw in claims involving rediscoveries of lost arts. The ancients reluctantly gave up their instruments of copper, despite long-established customs, traditions and prejudices. Romantic lost secrets can not account for the great revolution.

It was the same sort of change as that in which copper itself had terminated the old Stone Age long before. Copper tools lost out in a competition with something better.

On a drowsy summer evening, August 8, 1921, in the front office of the *Pittsburgh Gazette Times,* the writer was at his desk behind the counter, with little to do but watch the clock and wait for the midnight relief. The early editions of the paper dated August 9 carried a story which made a lasting impression on this particular young loafer. On page one, with big black headlines, there was spread the story of Walter Bunton, who had "modestly admitted" that he stood on the threshold of fame and fortune. He had just rediscovered the lost art of hardening copper, a secret which had been hidden since ancient times.

Headlines, pictures, editorials, interviews, denials, speculations—the newspapers, especially those of the Middle West, had a field day.

It seems that Walter Bunton was a young man aged about 27, living in La Porte, Indiana, and employed as a machinist with the New York Blower Corporation of that city. He claimed to have been experimenting with the idea of hardening or tempering copper for several months without getting any results. Then one night he had a "sudden inspiration." The new idea was tried out and success crowned his efforts.

Another widely published version of the events leading up to the discovery was that Bunton happened to find some pages torn from an old encyclopedia, "lying on a trash pile ready for the match." A picture caught his eye and then he chanced to see an article about "an old Roman metallurgist, incidentally a murderer of renown, who knew how to temper copper." Thus it came about that Walter Bunton, "untrained in great universities, not the product of great laboratories, not a skilled chemist or metallurgist," was led to make the marvelous discovery.

The sequence of events, both real and imaginary, was certainly not clear to the reporters, perhaps not even to the inventor himself. At any rate, Bunton maintained that he had been lured to Gary, Indiana, on August 2, by a gentleman named Carl Miller, of St. Louis. Miller was said to have escorted Bunton to a luxurious office near the United States Steel Company plant, where he was introduced to several officials, including Judge Gary himself. A demonstration of the hardened copper tools easily proved them to be all that was claimed.

"'Name your terms,' said Judge Gary." ("Nothing indecisive about Gary," commented the *La Porte Herald.*)

"'One million dollars and two cents a pound royalty,'" said Bunton. (Walter was also in pretty good form).

And so it was arranged that Bunton was to get some hard cash for his hard copper, although no money was to change hands for two or three months, until the discovery had "gone the rounds of the foreign patent offices." In the meantime he was not at liberty to divulge the secret of his process, which was understood to be some sort of "heat and acid treatment."

The story broke in the newspapers and Judge Gary immediately denied everything. It then occurred to Bunton that

he must have been duped by a gang of crooks and he was very glad that he had not given them "the formula and process."

Letters and telegrams poured into La Porte. A wire from Winthrop Smith and Company of New York offered Bunton two million dollars and four cents a pound royalty. He stood ready to board a train for the metropolis, but his attorney could not locate the optimistic organization responsible for this philanthropic proposal. Manufacturing concerns "deluged" him with "alluring" offers. A mysterious Japanese in Chicago was eager to put the inventor in touch with Japanese government officials. On this issue Bunton was adamant; "'the discovery must bring the most good to America,'" he declared.

A few of the letters Bunton received were congratulatory, some of them were of a begging nature, and many were from women who were enthusiastic about sharing the wealth with him; object mat., as the want ads in the personal columns so charmingly put it. In the end, however, Bunton remained true to his Michigan City sweetheart.

Unquestionably the *Gary Post* was a little harsh in its statement that "Bunton is either seeking notoriety or is loose in his upper story." But the fact remains that he was woefully shy of specimens and documents to support his assertions. Bunton could not seem to locate the important letter which led to the Gary excursion and that did annoy him very much. It is fitting that this brief review of the incident be closed with a revealing sentence which appeared in the *La Porte Herald.* "The last time he remembers having the letter, he said, was when he had it in his coat pocket on a trip down town to locate a reporter."

While the more sensational stories about hard copper have been featured in the daily newspapers, the technical journals have had a fine time arguing the matter pro and con, with the emphasis on the con. The names appearing in these accounts represent all degrees of scientific attainment up to and including that of Michael Faraday.

Many years ago, in the course of his researches on metallic alloys suitable for cutlery, Faraday produced a copper that was uncommonly hard. It took as keen an edge as anything found among ancient relics. A razor made of this copper proved to be quite serviceable and, really, there were but two considerations which tended to discourage further developments. In the first place the alloy was inferior to finely tempered steel and in the second place it was more expensive.

At one time a manufacturing concern called the Eureka Tempered Copper Company, of North East, Pennsylvania, was producing a copper said to be hardened by a secret process. Almer Thomas and Luzerne Merket were the names of the gentlemen to whom the discoveries were attributed. Their claims were investigated in 1890 by a subcommittee of the Committee on Science and the Arts for the Franklin Institute of Philadelphia. A few chemical and physical tests were applied to the metal, but the most interesting feature of the report given to the institute involves the questionnaires ("circulars" in those days) sent out by the committee to 100 establishments supposed to be using the Eureka hardened copper. The returns may be tabulated as follows: 5 "unable to see any difference"; 6 "claims—not substantiated"; 8 "tried for certain purposes—evidently was unfit"; 34 "highly favorable"; 47 apparently made no reply. This array of figures convinced the committee and it was recommended that the Franklin Institute award to the inventors its John Scott Legacy Medal and Premium.

The name of S. R. Dawson was for some years the center of an important

hard copper controversy, because this gentleman made repeated attempts to popularize his products. The late William H. Bassett, formerly director of research and metallurgist for the American Brass Company, told the writer that the activities of Mr. Dawson extended from about 1911 to 1922, and possibly over an even longer period.

An article published in *The Metal Industry* in 1916 stated that the Dawson process was "the secret of the inventor," but that "after the metal has been once treated by him it may be transported anywhere and remelted any number of times without a change in its quality." Whatever the secret process may have been, concealing the chemical composition was another matter and Mr. Bassett is authority for the statement that the copper contained from 17 to 18 per cent. of tin and about one half per cent of nickel, which gave the alloy its fine-grained structure.

The Dawson Hardened Copper was recommended for high-speed journal bearings, marine engines, trolley-wheels, watch springs, phonograph needles, locomotive links and link blocks, but it did not dodge the issue of cutting hardness. In fact it was in the realm of shears, razors, surgical instruments and cutlery in general that Mr. Dawson exerted his greatest efforts. It was argued that these copper implements were resistant to fruit acids, antiseptic solutions and all ordinary agents of corrosion. Circulars accompanying the tools described how they could be made to take and hold a keener and finer edge than steel, "if sharpened as directed on the reverse side hereof." Mr. Dawson appears to have believed in his products, always using scissors made of copper and shaving himself with a copper razor.

At one time Mr. Dawson maintained an office on Vanderbilt Avenue in New York City, but his persistent efforts to engineer this particular type of comeback for copper were not destined to meet with any great success.

On July 6, 1924, another one of the more spectacular hard copper stories hit the front pages of the newspapers. As the dispatches to the *Pittsburgh Gazette Times* (where the writer was again on the job to note and remember) expressed it, "what scientific men have been trying to do for 2,000 years . . . an obscure mechanic of little education and scientific knowledge is said to have done in a brief period of a month of experimenting."

The discoverer was James Earl Cummings, of East St. Louis. He had been cleaning the copper gaskets for his car, "a low priced machine of long service and worn aspect." While dipping the gaskets in a "chemical mixture" he was surprised to find that one of them would always spring back to its bent form whenever he tried to straighten it out. Mr. Cummings happened to describe his experience to some of the boys and one of them immediately exclaimed, " 'Jim, if that's true, your fortune is made.' " Jim decided to do some experimenting and to patent his formula.

A copper company invited him to Detroit and he had no trouble convincing them with a few simple tests. On July 5 he admitted to reporters that he had received a check for $1,500,000 and expected a royalty on every 100 pounds of copper produced. An article in the *New York Times* told of his being besieged by salesmen of bonds, stocks, insurance, homes and cars. Mr. Cummings, however, informed reporters that, " 'I don't reckon I will buy a car for a while. No, I shall keep the old car. It's good enough for us. And anyway, the car is responsible for my good fortune.' "

When he was telling about being "knocked cold" by the "cool million and a half" check, he made another remark

which rather neatly summarizes the East St. Louis incident. "'It's all like a dream, really,'" said James Earl Cummings.

A year later the old, old story was coming from Lorain, Ohio. A Negro labor foreman, E. E. Harrison, had devised a secret process for hardening copper by heating the metal in a vacuum. The usual reference to the ancient Egyptians was strangely missing from these reports, but otherwise they ran true to form. A new peak price of *three million dollars* figured in the offer of the old reliable "Eastern capitalists." The inventor's attorney, Victor J. Evans, of Washington, flatly refused to accept the sum offered by the greedy interests.

Perhaps Mr. Evans was doing what he thought was best for his client, but it would have been much nicer if he had permitted Mr. Harrison to do his own refusing. After all it is not every day that one has the opportunity to turn down three million dollars.

Newspaper editors seem to have become a little more suspicious of hard copper claims. Not so many of the stories about rediscovered lost arts—tales so closely akin to those renowned, ever-recurring, half-legendary dispatches in which Alexander Woollcott delights—have been able to break into the public prints of late. It would be a pity if they were to disappear altogether. It is a fascinating study, as Mr. Woollcott has pointed out, to note the peculiar twists and turns these stories exhibit, especially in their minor details.

Thus it is a real disappointment to find that in its edition of April 16, 1929, the *New York Times* must squeeze into a few lines on page 13 the exciting report that John Cameron, mechanic, and Hugh Webster, bank clerk, of London, Ontario, have accidentally "discovered the art of tempering copper" which will "revolutionize the use of copper in industry."

Or again, buried in the March 12, 1934, issue of the *Indianapolis Star*, one may find the item of only nine lines which tells of Riley Jones, of Chippewa Falls, Wisconsin, who has perfected a razor of "copper unmixed with an alloy" which has been "tempered to the hardness of steel" in his little home workshop.

There have been many others in the past and there will be many more in the future. Another big story for the front pages is just about due.

The search goes on. Only a fool would dare to be dogmatic about what can or can not be done.

It is the generally accepted opinion that the ancients did indeed know how to harden their copper. But the methods they used are still available, and painstaking research has produced some copper alloys which have a hardness exceeding that of any copper relics known to have been made in olden times.

One may read in technical journals the long record of advances in the development of more efficient copper alloys. Harrison E. Howe, editor of *Industrial and Engineering Chemistry*, recently showed the writer an alloy of copper and beryllium which was hard enough to cut mild steel. Many combinations have been tried and will be tried in the effort to secure greater hardness without sacrificing the unusual toughness and durability of the metal.

Some time, perhaps, the magic method will be found. The old red metal may once more compose the tools which will carve the steps of progress to a new and better age.

SOME RACE PROBLEMS IN SOUTH AFRICA

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Introduction

Race problems in the sub-continent of South Africa, from the point of view of the admixture that has gone on there in the past and that is going on there more and more, have hardly been reported upon from a broad, basic aspect. This is perhaps to be regretted, because in that sub-continent the white man (whether of British or Dutch ancestry) is living amidst a negroid population about four times as numerous as his own. Will the white race maintain itself and keep relatively pure, or will it be swamped in miscegenation, with a resulting mongrel population of somewhat brown color? There are different views on the answers to these questions, and I have heard both questions answered in the affirmative in South Africa, though laws are now being enforced against miscegenation between white and black.

In order to indicate the major impacts of the whites on the natives in various parts of South Africa, the following events are significant. The Cape of Good Hope was discovered by Bartholomew Diaz in 1486, while a little later in 1497 Vasco da Gama rounded the Cape and sailed on and named Natal. Saldanha discovered Table Bay in 1503. English ships first visited Table Bay in 1591, while the first Dutch fleet appeared in South African waters soon after in 1595. In 1620, the Cape was annexed by the English in the name of King James I, but was not garrisoned. The Dutch East India Company sent out van Riebeeck in 1652, and a settlement at Cape Town began. Cape Colony was first surrendered to the English in 1795, while Grahamstown in Eastern Cape Colony was founded in 1812 and Port Elizabeth in 1820. It was in 1835 that Durban was founded.

It may be mentioned that the officially estimated mean population of the Union of South Africa for 1933 was 8,369,200 persons, comprising 1,889,500 Europeans; 5,681,100 Bantu; 196,400 Asiatics, over 80 per cent. of whom are in Natal; and 602,200 Colored persons, 90 per cent. of whom are in the Cape Province. If Rhodesia and South West Africa are included, the proportion of natives to whites is increased.

Remarks on the Native Races

There are three principal elements in the South African native population, namely, the Bushman, the Hottentot and the Bantu, the sequence of their arrival in South Africa being in the order indicated.

The Bushmen are a primitive people, short of stature, slim, muddy yellow in color, with small tufts of rusty brown, woolly hair, giving a peppercorn appearance. Their skin is greatly wrinkled. They have low foreheads, prominent cheekbones, small, sunken eyes and ears with very little trace of lobes. Their noses are small, flat and broad. Their jaws project only a little. They have hollow backs due to inward lumbosacral curvature, making the buttocks appear prominent. They are wandering hunters who use bows and poisoned arrows, do not build huts, are independent and are users of an isolating, non-inflexional language with characteristic clicks. They are makers of rock paintings.

The Hottentots are of medium stature and slight build, with small hands and feet. They are reddish-yellow in color, with narrow heads, black woolly hair,

high cheekbones, hollow cheeks, pointed chins, eyes far apart, ears with moderately developed lobes and broad, flat noses. A fair degree of prognathism is present. There is marked lumbosacral curvature and characteristic steatopygia. They are nomadic pastoral people who build beehive huts grouped in kraals, have tribal organizations and use an Hamitic inflexional language, also rich in clicks.

The Bantu represent the greatest number of natives. They are a dark-skinned negroid race, but browner than the Negro. They are well built and many tribes are rather tall. Their hair is black, rather short and crimpy or woolly. They have full cheeks, large prominent eyes, thick lips, platyrrhine noses and prognathous jaws. Their hands and feet are large. The Bantu came in waves from the north, where there had been an infusion into their negroid stock of Semitic and Hamitic blood from contiguous tribes. They were rather warlike stocks, who sent out raiding parties to rob other tribes of their cattle, the latter being of great importance to them. They build kraals, often of considerable size. Their languages are formative and inflexional, with many linguistic groups and tribal dialects.

It is not within the purview of this paper to discuss at length the very difficult and conflicting accounts of the early native races of South Africa, complicated by waves of immigration, racial differences and intertribal wars, but only to give a background indicating how the present native tribes[1] have come to be in South Africa, their varying geographical distribution (see map) and their miscegenations.

The Bushmen occupied most of the mountainous districts in the earliest days of South African history. To-day, they are chiefly in the Kalahari and South West Africa. Using bows and arrows, they were more than a match for the pastoral Hottentots, who were numerically stronger, and ultimately the Bushmen were driven away by the whites and the Bantu.

The Hottentots, known to Arabian geographers in the tenth century as Wakwaks or Wa-Khoikhoi, were at that time south of Sofala on the East Coast of Africa. Another group of Hottentots was found near Benguella on the West Coast in 1667. There may thus have been two streams of these immigrants from the north. When the Dutch settled at the Cape, the Hottentots were not known to range beyond the Orange River. In the sixteenth and seventeenth centuries they had inhabited the valleys of the Karroo rivers. Now the two chief sections of the Hottentots, the Korana and the Namaqua or Naman, are largely in the western part of Southern Africa, but a large number of subtribes were recorded in the early days of white colonization. It may be mentioned that the Bushmen were sometimes termed Mountain Hottentots by some of the early observers. There were numerous migrations of the Hottentots northwards and northwestwards as European occupation increased, some tribes dying out and others amalgamating with other tribes in the process.

It may be remarked that some authorities consider that the Bushmen and Hottentots belong to a common Bush race, because of certain physical resemblances between them. There are few pure specimens of either race now-a-days. That Hottentots are crosses between Bushmen and Bantu can now hardly be sustained, but it has been suggested that Hottentots may have originated in the past by the crossing of Bushmen with some northern Hamitic negroid race before the Hottentots migrated.

The Bantu, the present dominant native race in South Africa, arrived there in a series of waves of invasion from the north, perhaps from East Central Africa. There is no doubt of

[1] Many variations in orthography of names of tribes occur.

their northern origin. In the eighth century, the Bantu were known to Arab and Persian traders on the East Coast under the names of Kafir (infidel) or Zeng (black). Probably at this time they were living in the area now known as Northern Rhodesia. As recorded by El Masudi in the tenth century, the Bantu tribes were known to be around Sofala, having crossed the Zambesi but not the Sabi River. The Hottentots or Wakwaks were then to the south of them.

Apparently there were three main streams of Bantu migrating southwards by the west coast, the east coast and more or less central routes, conquering and mixing with their predecessors as they went.

The Bantu migrating by the western route became known as the Hereros. They settled south of the Cunene River and around Lake Ngami and extended to the Atlantic. They included the modern Ovambos or Ambos and sub-tribes. Under European rule, especially during the German domination in South West Africa, some became scattered and a few entered the Waterberg district of the Transvaal.

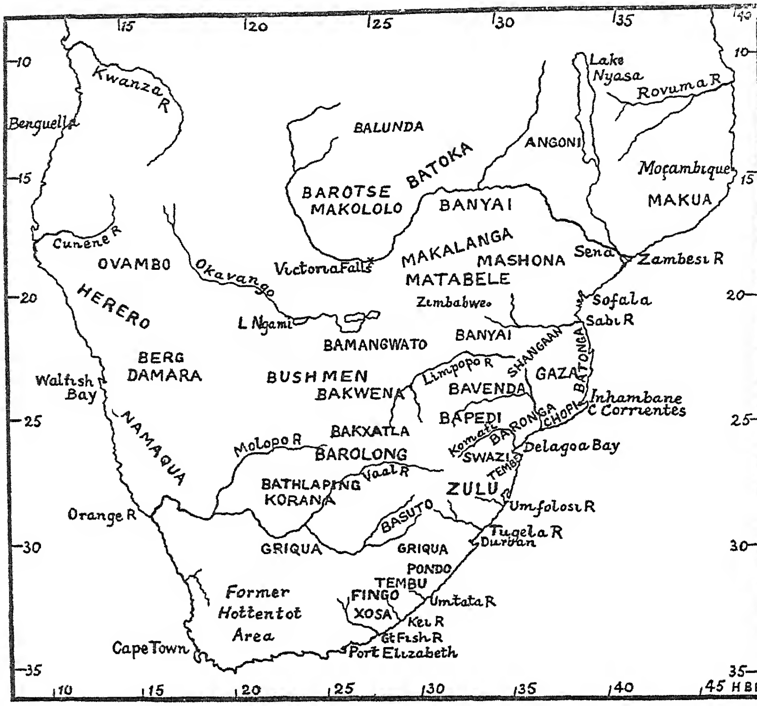
The most important streams of migration were those by the East Coast. Of these, four linguistic groups of Bantu can be distinguished, and these seem to correspond to some extent with waves of invasion. These four groups are the Makalanga and the Bechwana traveling inland and more central, and the Bathonga or Baronga and the Zulu-Xosa or Zulu-Kafir along the coast. The Bechwana and the Zulu-Kafir are especially important. For convenience each of these groups may be considered separately. Their later distributions are indicated on the map.

The Makalanga group includes a series of tribes such as the MaKalanga in the west, the BaNyai in the north and the Mashona in the east of Southern Rhodesia. In the sixteenth century the chief of the Makalanga was known as the Monomotapa, who ruled over a great empire in what is now Rhodesia. His subjects raided south to the Matopos. The Mashonas in the past occupied the Sena district and have now moved south. The BaNyai occupied the south bank of the bend of the Zambesi and some have migrated south.

The BaRotse and BaLundi crossed the Zambesi at different periods during the eighteenth century. The BaRotse are now the dominant tribe on the Upper Zambesi in Northern Rhodesia and, according to Coillard, came from the east and claim kinship with the BaNyai. Early in the nineteenth century, the BaRotse were subdued by the MaKololo, a section of the Basuto, who are members of the Bechwana group. The BaRotse successfully revolted against the MaKololo in 1865. The BaToka of the middle Zambesi basin probably belong to the Makalanga group.

Here may be mentioned the BaVenda, a composite group of tribes, who now occupy the northeastern part of the Zoutpansberg district in the Northern Transvaal, having conquered and absorbed its previous inhabitants. They left Mashonaland perhaps about the end of the seventeenth century and have a definite Makalanga strain in them as well as some Bechwana.

The Bechwana group comprises a series of tribes, whose language is different in pronunciation from other Bantu languages, but among the tribes there is similarity of both language and customs, the name Bechwana meaning "the people who are alike." The pioneers among them were the BaLala and BaKalahari. They penetrated south and, mixing with the Bushmen, came to live near Potchefstroom. Other Bechwana tribes penetrated to the neighborhood of Rustenburg; others settled around Kuruman. The BaThlaping went further and represent the southernmost advance of the Bechwana, having reached the Lange-



MAP SHOWING APPROXIMATE DISPOSITION OF CERTAIN AFRICAN NATIVE TRIBES AFTER THE ZULU CONQUESTS. CIRCA, 1840.

bergen, a region west of the junction of the Vaal and Orange Rivers. They have intermarried with the Koranas.

The BaRolong formed the next wave of invasion, became important but subsequently broke up into a number of tribes, some of whom had constant feuds with the Basutos under Moshesh. The BaMangwato are a branch of the BaRolong, who settled and remained on what is now known as Khama's country in the Bechwanaland Protectorate.

Another important clan, the BaKwena, gradually passed into the Northern Transvaal. They became involved in internecine warfare and split up. Some passed southward and settled on the Caledon River and surrounding areas, forming the Basutos of modern Basutoland. As already noted, a section of the Basutos, the MaKololo, went north into Barotseland. The BaKxatla settled near Mochudi in Bechwanaland and later were known as Linchwe's tribe. The BaPedi are Sekukuni's people in the Transvaal There are other Bechwana tribes which need not be considered here.

The AmaThonga, BaThonga or BaRonga group comprises tribes who speak dialects of a language called Thonga or Tonga. These tribes were migrants from various regions, driving out and absorbing the previous occupants. The BaTonga were known to be occupying the district between the Sabi and Inhambane Rivers in the sixteenth and seventeenth centuries, and attempts were made to establish Christian missions among them about 1560. Another division is the BaChopi, who still occupy the country between Cape Corrientes and the Limpopo. Another tribe is the Tembe with several offshoots in the Komati River basin and a little south, speaking the Si-Ronga dialect. The Tembe are said to be of Kalanga extraction. There has been much raiding

and intermixing, and the people of the Thonga group now form the natives of the areas of Inhambane and Lourenço Marques (Delagoa Bay) in Portuguese East Africa. Some of them were raided by the Zulus and fled from Natal over the Lebombo Mountains into the Lydenburg district of the Transvaal. The so-called Shangaans, who have much Zulu admixture, speak Transvaal Thonga.

The great Zulu-Xosa or Zulu-Kafir group was reported to have been near Sofala in the tenth century and was definitely further south in 1553, when wrecked seamen found the region between the Umfolosi and the Umtata Rivers occupied by Bantu tribes, probably Zulu-Xosa or their Xosa division, whose speech was different from Tonga.

The AmaXosa, AmaPondo, AmaTembu and AmaPondumise (generally referred to as Xosa, Pondo, etc.) are tribes whose first chiefs had a common ancestor. They were the first wave of the Zulu-Xosa invasion along the East Coast and advanced as far as the Great Fish River, encountering Hottentots on the way. They fought nine Kafir wars against the whites between 1779 and 1877. Many of them still live in the Transkei, a native reserve.

The Great Abambo group of tribes occupied Natal in the seventeenth century. Some 95 of them were known about one hundred years ago. There are somewhat divergent accounts of the relationships between the tribes and the sanguinary conflicts that occurred among them at the beginning of the nineteenth century. One warrior tribe in Natal was the Vatwah or Endwandwe; another was the Mtetwa, of which the Zulus were a section. The Zulus became a great raiding people under their chiefs Tshaka and Dingaan. Tshaka had a great capacity for wise leadership and built up the Zulus into a formidable warrior nation by rigorous selection and discipline. The Zulus under Tshaka from 1818 to 1828 maintained a reign of terror. Resultant on Zulu raids, some Abambo tribes fled and united as Swazis; the Vatwah, driven north beyond the Zambesi, became Angoni; others became Gazas, had internecine strife and one section became the Shangaans, who mixed with the Thongas. Some Vatwah joined revolters against Tshaka, they united as Ma-Tebele, ravaged the Transvaal, annexed Monomotapa and became the foe of the Mashona. In 1828 Tshaka was killed by Dingaan, who massacred some Dutch trekkers or emigrants in 1838, was then defeated by the Dutch, fled to and was killed by the Swazis. The Zulus were subdued by the British in 1879. Five other large Abambo tribes, defeated by the Zulus, fled south and fought Xosa, Tembu and Pondos, all the defeated parties, with remnants of other tribes, becoming Fingoes, that is, destitute, who were ultimately protected by the British.

Native Hybrids

It will be realized that, while in the course of time, many of the tribes living in South Africa have become more or less consolidated, yet in practically all of them intertribal admixture has taken place in the past. Tribal wars of conquest were usually concluded by the conquerors killing all the male vanquished and absorbing the conquered women into their own tribes. While a general racial type may have been perpetuated, yet differences occur among its components and, at the present time, numbers of natives, especially in the Cape Province, have little idea of their true tribal origin. Tribal crossing by intermarriage has further complicated the native race problem.

Among hybrid people of mixed native origin a few examples may be given. The Korana are Hottentots with some Bushman admixture. The Berg Damara, who speak a Hottentot language, are early Bantus with Bushman and Hottentot blood. The BaTamaha, near

Potchefstroom, are a mixed tribe of BaLala and Bushman origin. The MaSarwa or Vaalpens. hybrids of Bushmen and BaKalahari, are the cattle herds of the BaMangwato. The BaThlaping are a Bechwana stock who married Korana wives and in such crosses the Bushman and Hottentot (or Bush) characters are dominant to the Bantu. In the Lydenburg district the Amabae (BaMbayi) have resulted from intermarriage between Basutos, Thongas and Swazis. The Tambuki are hybrid Bushman and Tembu.

Undoubted "ethnic melting pot" areas occur in South Africa. Among these may be mentioned the Kalahari, where Bushman-Hottentot admixtures have been impinged on by Hereros from the north and by Bechwana on the east. Another area of hybridization is around the junction of the Vaal and Orange Rivers as far as the Nokana River on the west and Kuruman and Taungs in the north, where Bushmen, Korana Hottentots and Bechwana, like the BaThlaping, come together. Yet another is the area of the Northeastern Transvaal extending into Portuguese East Africa, where BaVenda, BaPedi, Thonga and Zulu admixtures have occurred.

Under British and South African rule, tribal wars have ceased—sporadic quarrels among small clans only occur nowadays, and these are unaccompanied by conquest and absorption. Urbanization of natives in South Africa, particularly of the men, who go to the towns as domestic servants, employees in manual work in shops and building trades and as laborers on the gold, diamond and other mines, is playing a great part in breaking down tribal distinctions and intertribal prejudices.

The White Population of South Africa

The white population of South Africa is composed of a number of elements, and a white problem may be said to exist there. However, the very heterogeneous assemblage of representatives of Europeans settled in South Africa seems to show signs of blending into a more or less homogeneous congeries under the name of South Africans. Among the younger generation quite a number are unaware of the place of origin of their ancestors, and first express surprise at the inquiries and then interest when told of the etymological significance of their family names.

The predominant elements in the white population are the British and the Dutch, who together form the bulk of that population. The early Portuguese navigators did not settle permanently. It was in 1652 when the Dutch leader, J. van Riebeeck, arrived that settlement began. The Dutch began to import slave labor, largely from the Dutch East Indies. in 1658, while they also utilized the Hottentots as servants. A number of French and Belgian Huguenots arrived in 1688, but their language was soon suppressed and they became absorbed into the Dutch population. The Huguenots introduced winemaking, the Dutch having already introduced viticulture. There have been repeated struggles for supremacy between the British and Dutch since about the end of the eighteenth century, resulting in sundry northward and northwestward migrations of the latter (especially the Great Trek of 1836) and the formation of republics in the Transvaal and Orange Free State about the middle of the nineteenth century. British settlers came to the Eastern Cape and to Natal early in the nineteenth century. The Cape Province, with its increasing numbers of annexed Native Territories, continued under British government. After the Anglo-Boer War of 1899 to 1902, the Republics became British territory and in 1910 the Union of South Africa was created. Racial feeling between the British and Dutch was fomented by some diehards, but

most of the great leaders, including Botha and Smuts, loyally kept their oaths of allegiance and endeavored to allay racial feeling. To-day, among young South Africans, intermarriage of Dutch and British in many cases is taken as a matter of course, without regard to nationality. The contracting parties, though of different stocks, think nothing of this—they are South Africans. Where children of British-Dutch ancestry have grown up, it has been of interest to note the great influence of the mother and the mother's nation on them. In many cases, if they express sympathy at all, it is with their mother's people and their ideals.

In addition to the Huguenot element in the Western Cape, mention must be made of a strong German element in parts of the Central and Eastern Cape (then British Kaffraria) due to settlements of Germans as colonists about the middle of the nineteenth century.

For the last two generations, many admixtures of European peoples have occurred in South Africa. Predominantly there is the British-Dutch cross. In addition, there are other crosses involving members of practically all European nations. The groups of such European admixtures may be small, but they act as a leaven in the community.

With the development of diamond mining (after 1867) and of gold mining (especially after 1886), men and women of many nationalities found their way to the diamond fields and to the gold mines. As in every mining camp, a heterogeneous European population was soon reinforced by native laborers and then penetrated by traders, many of whom were Russian and German Jews.

Emigration from Central Europe and from the Baltic areas has recently added a number of races to the European population. Such emigrants include Lithuanians, Latvians and Esthonians, many being of the Jewish faith.

One sad feature in South Africa is the existence there of the class known as "poor whites," not well enough equipped mentally for skilled work and, though often physically fit, with no unskilled labor which they can do, because unskilled labor is performed by natives and not by whites. Many circumstances have contributed to the making of the "poor white" class. These can not be dealt with in any detail. It must suffice to mention the effect of Roman-Dutch law on land subdivision, isolation of small settlements, intermarriage with near relatives and with Cape Colored (Eurafrican) people, successions of droughts and bad seasons, increase in feeblemindedness due to inbreeding and isolation, and also ingrained laziness (due to their dependence on natives to do all the hard work), which now has become second nature. Unfortunately, the "poor whites," of whom the vast majority are of Dutch stock, are very prolific and their children have a similar mentality to themselves. It has been estimated that up to 150,000 "poor whites," forming about 8 per cent. of the total white population, are in South Africa.

Eurafrican Admixtures

Problems created by hybridization between whites and natives have to be considered. An Eurafrican race, generally designated as Cape Colored, is found chiefly in the Cape Province. At present these Cape Colored people are about equal in number to one third of the white population of the Union of South Africa. Hottentot women taken into the families of early white colonists, their Malay servants and slaves and Kafir women of various tribes who became servants, mainly constituted the Cape Colored progenitors. In the Western Cape it would seem that Hottentot women were the usual ancestresses, and in the Eastern Cape Province, Xosa, Tembu and Fingo women intermarried with many types of European males.

In other parts of the country other native women were concerned. Eurafrican admixtures were also perpetuated in the early days of colonization by misguided European missionaries who hoped thereby to win converts, and by visiting traders who wished to increase barter. More recently, small storekeepers and pedlers on trading circuits have added to the Colored population by miscegenation, and more casual visitors, such as come into ports, have contributed to a slight extent.

So far as European women are concerned, few white women in the past married with native men, and only did so if in dire distress, as in the case of destitute widows with young families for which no white man would take the responsibility; such unions are not now allowed. Marriages between European women and Colored men also are not common.

Some hybrid Colored people form distinct groups. Thus, the Griquas arose from matings between early Dutch colonists and Hottentot and Bush women. The Rehoboth Bastards are also hybrids between Boers and Hottentot women; they trekked north into South West Africa. Roving whites, such as Coenraad Buys at the end of the eighteenth century, mated with native women and raised numerous progeny who formed groups in various parts of the country.

From 1917 I have had the opportunity of investigating a number of newer cases of Eurafrican admixture as well as of Asiatic intermarriages with native and Colored peoples, several generations being studied, and as many members as possible of the families being considered from their physical, mental and social aspects. Unfortunately, photographs usually could not be obtained, owing to strong objections by some of the parties concerned.

One example of relatively simple miscegenation may be given in some detail. A fair-haired, blue-eyed Belgian married a Zulu woman. They had eight children. The actual proportions of white and native blood in the descendants are indicated in the upper portion of Fig. 1. However, the members of the family classify themselves, approximately correctly, as white, black and brown. These grades are based on skin color, as is indicated in the lower portion of Fig. 1. Thus, the eldest daughter is very dark and described herself as "a proper black woman like my mother." She dislikes the brown members of the family, referring to them as "trash."

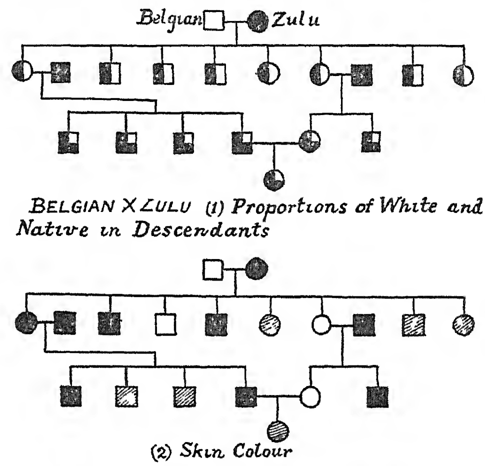


FIG. 1

The second member is a very dark man. The third, a man, is "white" and is much disliked and despised by the rest. The fourth is a black man, the fifth, a woman, is brown. The sixth, a woman, is "white," while the seventh, a man, and the eighth, a woman, are brown.

The very dark eldest daughter of the F_1 generation is married to a pure Natal Zulu. They have a family of four sons, two described as black and two as brown. The "white" woman of the F_1 generation married a Zulu and has one black son and one "white" daughter. Intermarriage has occurred in the F_2 generation, the last-mentioned white daughter having married the younger black son of the eldest daughter of the

F_1 generation. They have one brown baby daughter.

Of the fifteen descendants of the original couple, six approximate to the Zulu type (black), three to the European (white), while six show intermediate skin color (brown). Socially, the white members are not popular with their Colored brethren, while the brown members appear to be despised by "white" and black alike.

A more complicated admixture, not easily charted, as details of some "in-laws" are lacking, has come from marriages between three families, each of mixed origin. These families may be designated A, B and C.

Family A was founded by a Dutch man and a Malay woman, who might have had some white blood. Of their family one son and his descendants are known. This son married a Colored wife. They had three children. The first was a daughter described as "white"; the second, a son, was a Cape boy, with light skin, European features but pouting lips and colored whites to to his eyes; the third son, described as "Cape-Dutch," married a woman who in herself united families B and C. Their six children will be considered later.

Family B originated in a marriage between a Norwegian man and a Hottentot woman. They had one son, who married a Colored woman of Family C.

Family C had a male ancestor who was either German or Dutch and had a Dutch name. He married a Kimberley woman, described as "white with a dash of color," having a white skin and black hair but a flat nose. Of their family, one daughter married the son of Family B. They had one daughter, who married the younger son of the F_2 generation of Family A, their children forming the third filial generation.

The father of the third filial generation is of Dutch-Malay and Colored blood. His wife combines Norwegian, Hottentot, German or Dutch and some form of slightly colored ancestry. Their family consisted of six children, two of whom died before they were four years old. The eldest is a daughter, married to a Dutch man, who passes as white and has two children. The second is a son who looks white but calls himself Cape or Colored, has black hair and eyes but European skin color and appearance, shows slight pigmentation round his finger nails, has the "native" trick of rolling his eyes and is betrothed to a Cape girl. The third, a daughter, resembles her elder brother but has frizzy hair. She has married a Cape man. The fourth and fifth children, sons, died young. The sixth, a son, is much darker than his brother and has pouting lips and coffee-colored whites to his eyes. He calls himself a Cape boy.

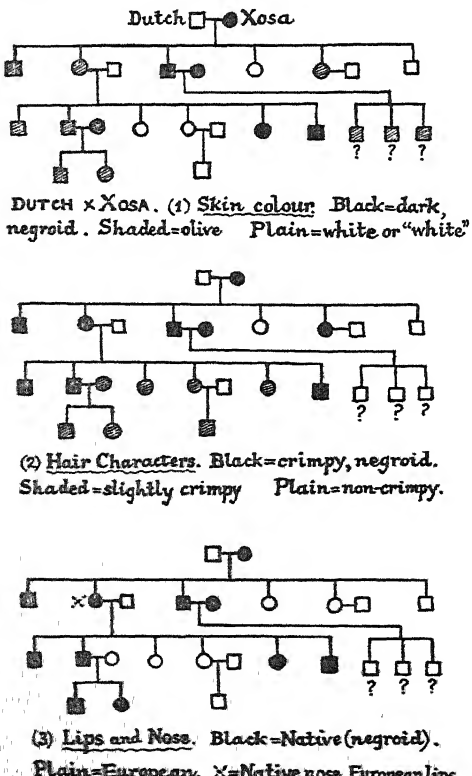
Most members of the family seem pleasant, respectable, fairly well-to-do people, sharply divided among themselves on the question of color. In the third filial generation, the native color has become diluted and some of its members pass for whites.

Many other cases of racial admixture have been investigated by me, but space prevents their presentation here. Accounts of some have appeared in the *South African Journal of Science,* Vols. XXII, XXIV and XXVII, but many of the newer cases are not on record. An outline of some further Eurafrican crosses may now be given, the families being numbered.

(1) A Dutch man married a native woman of unknown tribe, probably Bantu. They had a son who married a Basuto. One of their daughters married a fair Scotsman, another a Zulu. One child of the Scottish marriage is married to a Cape Colored woman, the offspring of a Norwegian father and a Colored mother. Four generations of this family have been investigated. All grades of color are exhibited among its members and all types of opinion. Within the

family dissentient views on racial admixture occur, but it is evident that the European element has not improved from the admixture. The native element has gained to a slight extent, but the Cape Colored members are in an anomalous position. One satisfactory feature is that some of the Colored race realize their position and are openly advocating racial purity.

(2) Another family arose from Dutch-Xosa miscegenation, which has been repeated by a son, while other children have married with other Cape Colored folk. Two filial generations are known in some detail. Altogether, there were fifteen individuals who varied from almost black to two members who pass as white. Most of them are brown-skinned. Their lips show Bantu features mostly. The hair in this family varies from frizzy or crimpy Bantu to fairly straight. The "white" members of the family are somewhat temperamental compared with Europeans and, under stress of emotion, give vent to their feelings in violent, hysterical outbreaks.



DUTCH × XOSA. (1) Skin colour: Black=dark, negroid. Shaded=olive Plain=white or "white"

(2) Hair Characters. Black=crimpy, negroid. Shaded=slightly crimpy Plain=non-crimpy.

(3) Lips and Nose. Black=Native (negroid). Plain=European. X=Native nose, European lips.

FIG. 2

(3) Another family originating in a Dutch-Xosa marriage has been investigated through three filial generations. Some of the results are shown in Fig. 2. The Dutch man may have had some admixture of Javanese blood. He married a Xosa slave girl. They had six children, of whom one man and one woman had light skins, and one man had dark and one man and two women olive-colored skins. Two men and two women had crimpy, native type of hair, and one man and one woman had straight hair. Two men and one woman had lips and nose of native type, the others had the European type of lips and nose. Of this generation, one dark man married a Xosa; they had three children, but nothing is known of them. One olive-skinned woman is married to a Dutch man. They had six children. Of the six members of this second filial generation, two women are "white," one man and one woman dark and two men olive-skinned. Three men have crimpy hair and three women slightly crimpy hair. Two are European and four native as regards lips and nose. One man of this generation is married to a thin-lipped Cape Colored woman and their children are typically Cape Colored. One woman is married to a Dutch man and their child is a masked white.

(4) A Dutch farmer married a typical Hottentot woman. They had two sons and three daughters. The eldest son married a Hottentot woman and had 14 children, of whom 9 are dead. One of his surviving sons married a cousin, who was the sole survivor of 10 children. These two have a family of three daughters, so far unmarried, who have olive skins, Hottentot hair and oval faces, with thin lips of European type. They also show slight steatopygia and two have high cheekbones. In the F_2 gen-

eration heavy mortality on both sides of the family is noticeable.

(5) A blue-eyed Danish sailor, employed in whaling, married a Xosa woman. They have two sons and a daughter. Their eldest dark-skinned son married a Cape Colored woman (origin uncertain), and they had three, not very bright, children. Of the younger son nothing is known. The daughter, olive-skinned and with European type of hair, is married to a Dutch man, their family consisting of two boys and one girl. One boy with blue eyes looks European, one boy has brown hair and negroid lips and the girl has flaxen hair and blue eyes but Bantu facies. These children are more intelligent than their cousins and they have more white blood.

(6) A German man, with hints of Colored blood, married a Hottentot woman. They have two sons and two daughters. One son and two daughters are largely of European appearance; the younger son resembles his mother but has a European type of nose. Of the daughters, one is married to a pure German and is in terror of her Colored blood becoming known. Their infant son is said to be like his father.

In this family, the first filial generation is physically weak and temperamentally unstable. The European influence is definite but varies in degree. The native influence is more obvious in the sons. There is antagonism between the whiter and less white members of the family, the former considering themselves white. The Hottentot mother is bitterly conscious of the position of some of her children. In her own words: "The whites look down on my family; the blacks spit at us; we are outcasts."

(7) An American Jew trader married a woman said to be a Basuto but having Pondo facial markings. Both were healthy. Their family consisted of four sons and five daughters, of whom three sons are dead. Four of the surviving children show Semitic characteristics, either in features, nose or hair. All are of poor physique, and intellectually none is well equipped. Syphilis of unknown origin has been contracted by two of them. Chest troubles are very marked in the family. Two (who are dark) are married, and the only child in each of the families is of poor physique.

(8) By intermarriage between members of two families, each of mixed origin, Portuguese, Dutch, Huguenot, Basuto and Javanese (Malay) blood is being combined. The characteristics of the families are summarized in Fig. 3. The founders of the first family were a Portuguese sailor and a Dutch woman from Java. One son married a Basuto and they have three children, one of whom, a man of weak physique and light brown complexion, married into the second Colored family. Of the daughters, one is Cape in appearance and married a Cape boy, the other is native in appearance. The second family was formed by a Huguenot who married a "Java slave girl." One of their sons married a Basuto. They had six

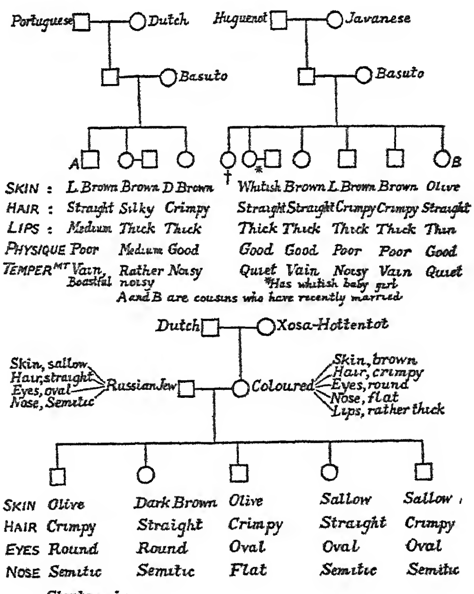


FIG. 3

children, one of whom is married to a Dutch man and has an infant girl, and one has recently married a man in the previous Colored family. One is dead, the others are unmarried.

In the second generation of the Portuguese-Dutch-Basuto family, the man shows the poor physique often seen in the European-Native cross, combined with great boastfulness. In the two women the native element appears to overshadow the European. In the Huguenot-Java-Basuto family, the men are also of poor physique and are unreliable and vain. The women consider themselves white and are light in color; their physique is superior to their brothers.

(9) The founder of this family was a Belgian Huguenot who married a Polish woman from Vilna. Of their children, one son went to South Africa and married the daughter of a Jewish trader and a Cape Colored woman (probably Dutch-Hottentot), their family being three sons and one daughter. Two sons are Jewish in appearance but with negroid lips, the daughter looks Syrian and is excitable. One son, of native appearance, has married a Basuto girl recently.

This family presents a curious admixture. The Belgian and Polish influence seems quite masked by Semitic and Hottentot admixture and, after the introduction of the native element, the progeny, especially the men, were of poor physique. Family pride and social ambition were noticeable, and the man who had a Basuto wife was despised by his relatives.

(10) A family that combines Jewish, Dutch, Xosa and Hottentot blood was initiated by a Russian Jew from Odessa who married or lived with a woman described by herself as a Bastard of mixed Dutch, Xosa and Hottentot blood. Five children have been born. Their characteristics are also shown in Fig. 3. The eldest boy shows steatopygia, indicating the Hottentot admixture of the past (his mother being heterozygous), his nose is Semitic, his eyes and hair of Xosa type, while his cheekbones are high like his mother. Another boy and two girls are of the Semitic type. The remaining child, a boy, is Cape Colored in appearance. Three of the children, all boys, have crimpy hair. The children did not show thick lips.

As in Family (7), the Jewish influence is very marked. In some parts of the Cape Province, for instance, in the neighborhoods of Port Elizabeth and Oudtshoorn, Cape Colored people with markedly Semitic cast of nose and countenance can often be seen. Europeans in these neighborhoods, intimately acquainted with local conditions, have expressed their opinion that these Hebrew-like Colored people "mark the path of the itinerant Semite pedlar," and there appears to be a good deal of evidence for this view.

Asiatics and Asiatic Admixtures in South Africa

Apart from the native and Colored elements in the population, other racial elements have been introduced in the past. As already stated, the Dutch East India Company used the Cape as a provisioning depot, and some of their European staff settled there. They brought with them their Malay servants (some Javanese), and their descendants still form a small separate group, the Cape Malay, living especially on the coast of the Cape Province, where they are expert fishermen, well known in Cape Town and Port Elizabeth.

The development of the diamond industry at Kimberley about 1867 led to the importation of Indian labor, chiefly from Madras. For the development of the sugar industry in Natal, Indian coolies, largely Tamil and Madrassi, were brought in as indentured laborers in 1860, native labor having proved not very satisfactory. Indian laborers also built the railway from the Point to Durban in 1860. The Indians liked the

country and remained there, the result being that much of the rich agriculture, including sugar, fruit and ginger, in the Garden Colony of Natal, is done by Indians to-day. These people, now about as numerous as the whites in Natal, form many small settlements, are thrifty and some employ natives to work for them. As Indian waiters and shopkeepers, particularly vegetable sellers, they have spread throughout the Cape, Natal and the Transvaal. A few wealthy Indian silk merchants have also settled in the country. At present, the government has arranged free repatriation of any Indians to India who so desire, but the conditions in South Africa are more attractive than those in India and but few avail themselves of it.

A short-lived experiment (1904–07) of the introduction of Chinese indentured labor on the gold mines of the Witwatersrand was a failure. Disease spread among them, quarrels and feuds occurred and the survivors were repatriated. Some Chinese are still present in South Africa, mostly engaged in growing vegetables, in laundry work and a few as shopkeepers and silk merchants. The presence of Asiatics in South Africa has led to various crosses with them, some of which may now be considered.

Afro-Asian admixtures form another group of the newer elements in South Africa, these including especially the progeny of unions between Indians and Kafirs, often due to insufficient numbers of Indian women compared with men. Such unions occur chiefly in Natal and a few in other parts of South Africa. Most of the Indians at present in Natal have been born in the country.

The characteristics of a family living near Durban, who combine Tamil (Indian) and Zulu blood, are given in Fig. 4. The father, a Tamil, born in Natal, is a tall, spare thin man, brownskinned, with oval features and eyes, thin lips and nose and straight hair. He is voluble and excitable. His wife, a Zulu, is well built, stout, blackskinned, with round features and eyes, thick lips and flat nose. She is of very equable temperament. They have three sons and three daughters. One son and two daughters resemble the father in brown skin color, two sons and one daughter are black like the mother. In this family the Bantu type of bodily build, hair, eyes and lips is dominant over the Indian, four of the six children showing such characteristics, but the distribution of the characteristics varies among the members. The children having native physical characteristics, however, are rather more refined in features than their mother, and the whole family is of better build than the father. In temperament the boys resemble the Indian father in being excitable, the girls are like the mother in being equable.

A number of other Indian-native and some Indian-Colored families are known

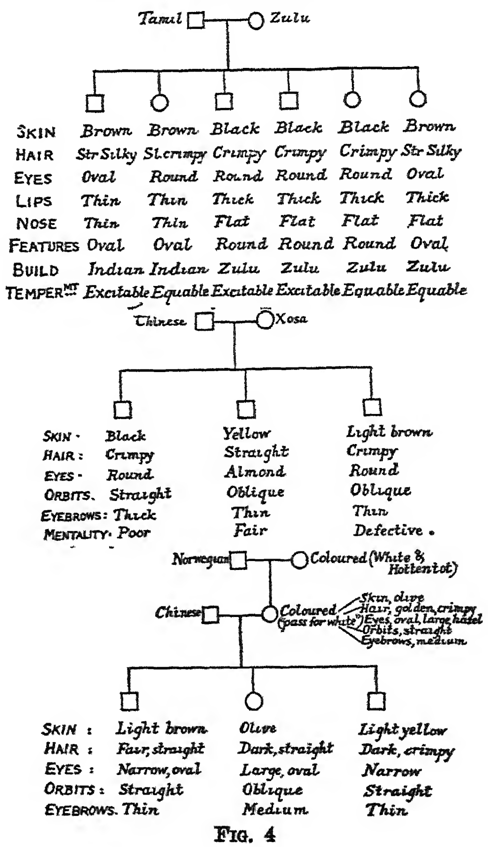


FIG. 4

to me but can not be dealt with in detail. Among them is a family derived from a Madrassi man and a Zulu woman. They have four children. The African type of hair, lips, nose and temperament is shown by three of them, the fourth showing mostly Indian characteristics.

A Transvaal family, founded by a Rajput man and a Shangaan woman, consists of two sons and two daughters. The elder daughter, mostly of Indian type, has married a Natal Indian and has two children of Indian facies but with rather crimpy hair. The younger daughter, native in type, has married a Shangaan and has two native-looking children. The elder son has married an Indian wife and their baby daughter, four months old when seen, apparently is Indian in appearance. The younger son has married a Colored (Dutch-Thonga) woman and their two young children are native in appearance.

Another family founded by an Indian of Bengali descent and a Dutch-Hottentot woman, consists of three sons and two daughters, all unmarried. The eldest son is Indian in appearance and temperament. The second son is largely Indian but with slightly crimpy hair. The third son is largely native in appearance. Both girls and one boy have high cheekbones and one girl shows steatopygia.

European, Asiatic and African blood are combined in members of the two last-mentioned families

Chinese admixtures are now being produced in small numbers by intermarriage between Chinese and natives and Colored people. A few examples may be given.

A Chinaman, born in Amoy but now living in South Africa, has married a Xosa woman, who has become dull and stupid. They have three children. The characteristics of the family are shown in Fig. 4 (middle). The eldest son looks like a pure native, the second son is typically Chinese and the third son combines crimpy hair with Chinese features and is mentally defective. Such a marriage between Chinese and full-blooded native is not common, but is indicative of what is taking place in the community.

The family whose characteristics are shown in Fig. 4 (bottom) was founded by a Chinese from Singapore. His wife is a Colored woman, the child of a Norwegian father and a mother of mixed white and Hottentot parentage. This woman looks European, with almost golden though crimpy hair. They have three children. The two sons have the general appearance of Chinese, though one has fair, straight hair and the other dark, crimpy hair. The daughter has almost a Syrian look, but with oblique orbits. The family seemed healthy, clean and prosperous.

A Chinese man, born in South Africa of Cantonese parents, first married a Chinese woman and later married a Colored woman of Dutch-Fingo origin as his second wife. Of the three Chinese-Dutch-Fingo children, one son and the daughter are of Chinese type, with straight hair and almond-shaped eyes, and one son is distinctly native in appearance and temperament. The hybrid family is of good physique and the Chinese characteristics are dominant.

A Chinese man married a Colored woman of mixed Dutch and native blood as his third wife, her two predecessors being Chinese. The five children of the last family show marked hybrid variation. One son is Chinese in facies but has a very dark native skin. One daughter has a yellow skin, scanty eyebrows, straight orbits, round eyes and crimpy hair. Another girl has brownish skin, straight hair, thick eyebrows, oblique orbits and narrow eyes. The second son is Chinese in appearance and the third son resembles his mother but has a yellowish-white skin.

A Chinese man, born in Kowloon, went to South Africa and married a Cape Colored woman of uncertain

origin. They have four sons and one daughter. The eldest son, of Chinese appearance and manner, has married a Cape Colored woman and has two sons, much like him. The second F_1 son is like his father in color and seriousness but is otherwise native. The third F_1 son looks and behaves like a native, is married to a Zulu woman, has two sons and a daughter of native appearance and one daughter of Chinese appearance. The fourth F_1 son looks like a Cape Colored man and is married to a woman born in the East Indies and said to be "part Chinese." The fifth F_1 member, a daughter, is dark-skinned, with negroid eyes and lips, is married to a Chinese and has two little boys of Chinese appearance

Many variations in physical features occur in this family, but, on the whole, the Oriental is dominant, and two of the first filial generation have shown their strong affinity and sympathy with the Oriental by their marriages.

The four families last mentioned are of much interest as they each clearly combine European, African and Asiatic blood.

Another Chinese admixture, but of a different type, has been observed in which the parties were an Indian man of Tamil stock, taken to South Africa as an infant, and a Chinese woman, who was born in South Africa. They had six children. The first-born, a son, died immediately after birth. The second, a son, is typically Indian in appearance and has a violent temper. The third child, a daughter, is Indian in appearance but is placid. The fourth child, a son, is now dead, but is described as being like his Indian father. The fifth child, a girl, is small, with a yellowish skin, oblique orbits and a violent temper; she looks Chinese. The sixth child, a boy, also looks Chinese and is placid in temperament.

In comparison with the Chinese crosses with African and Eurafrican, already cited, the Chinese characteristics, derived here from the maternal side, do not seem quite so evident in the offspring—but both parents are Asiatic.

Two cases of Eurasian admixture may be of interest, occurring, as they do, in a South African setting.

A German merchant married a very pretty Indian Tamil woman. After a stay in East Africa, they went to Natal. Their family consists of five children. Two of the sons married Natal Tamil women, one daughter married a German man. The elder son and his Tamil wife have two typical Tamil children and the younger son and his Tamil wife also have two children, both Tamil in appearance. The German-Tamil woman married to the German has three children, one son being distinctly German in appearance, the other son and daughter being nearer the Tamil side of the family in appearance and temperament. Social factors here have come into consideration. The families of like racial constitution are happier than the one in which there is a larger proportion of European blood, and there is mutual dislike between the cousins. The German husband of the German-Tamil wife is a Lutheran, while she is a Buddhist, and the children, so far, have been educated as Lutherans. The German-Tamils married to Tamils tend to be happier, for with them there is less upset of social ideas and of social inheritance.

A Scot married a high-caste Rajput woman in her home land. Twin boys were born to them, and after the parents settled in South Africa a baby girl was born. The boys are like their mother in features and hair and are strong and healthy. The baby girl had a quite fair skin when seen.

Remarks on Racial Admixture and its Effects in South Africa

The white population in South Africa, as already mentioned, is greatly outnumbered by the non-white, and many prob-

lems naturally arise therefrom, as well as from the impingement of the one race on the other. The whites constitute what has been termed an "aristocracy of labor." They are the originators and planners of schemes, supervisors and directors, manufacturers, farm proprietors, clerical, legal, religious and educational workers. The natives are the manual workers. The Cape Colored people are in an intermediate position. The Colored men are good market gardeners, and some attain considerable skill as house painters, carpenters, chauffeurs, mechanics' assistants, waiters and the like.

With increasing education of the Colored population and of the natives, the less well equipped of the whites, particularly the "poor whites," find themselves in difficulties. Because of their white skins, the "poor whites" consider themselves part of the "aristocracy of labor" and despise and often refuse to do unskilled manual work for which they are physically fitted—to them it is "Kafir's work." If willing to do such work, they find themselves in competition with natives, who are often more competent and easier to manage than themselves. For skilled work there are too many non-submerged whites, and the lower strata of white society, above the "poor whites," are finding themselves in competition, not only with the Cape Colored people, but with the better educated and more intelligent natives. It must be stated that the government has tried to rehabilitate the "poor whites" by land settlement in good irrigated areas and by labor colonies, but their numbers still increase.

The problem of feeblemindedness among the "poor whites" is of great importance. Racial deterioration due to undue proportional increase of the unfit is insidious and must be stopped. Segregation of persons with marked hereditary defects is necessary, and some means of preventing the propagation of the mentally and socially inadequate is absolutely essential for the continuation of white civilization. Recently, an increase in feeblemindedness among natives and Coloreds has been noted, and this needs careful attention.

In connection with feeblemindedness, there is the danger, as elsewhere, that high-grade morons may enter the Union of South Africa as immigrants, with the inevitable consequences. In regard to any scheme of immigration, the working skill of the immigrants, their standards of living, moral ideas, assimilability in the new land and the effect of their social characteristics on the established population need the closest consideration.

Social inheritance and racial admixture are closely connected and in subcontinents like South America and South Africa, where white and non-white live side by side, are of great importance. In South Africa, the natives are at a lower level of civilization than the whites; also, the Asiatics have different standards of living and morality. Social inheritance involves the ideals, sentiments, moral standards and general relations of life. A person instinctively adopts the relations of family, civic or tribal responsibilities that his parents did and, in the community, actions against the standard of life of that community are barred. The general average of communal or family behavior and attitudes towards life are thus maintained, the majority, from force of circumstances, remaining within the limitations imposed by inherited public opinion. Continuity is thus assured of the *best* opinions of preceding generations.

Racial admixture, even between whites, tends to break the continuity of thought and customs, especially when the crossings are between peoples not closely related by common origin, language, habits or religion. The contrast, naturally, is more marked between whites and

natives, who have very different outlooks on life. Scientifically, there are two great groups of fundamental differences between white and black; firstly, physical and mental differences due to inheritance, which are biological differences, and secondly, differences in religions, customs, traditions, ideas and their consequences, which are social differences.

From my studies of large numbers of Eurafrican crosses in South Africa, of which a few examples have been given, such crosses are not to be commended. There is invariably an alteration of social customs and loss of social inheritance by the offspring. The Colored race has not the energy nor the persistence of the white, is less stable temperamentally and is not controlled by the tribal conventions of the native. Dislike by them of the native connection seems general. Numerous social grades exist among the Colored people and those with more white blood despise those with less. In the lives of "mixed" families, there appear to be great inequalities: while the white parent tends to sink, to become more animal-like, less energetic and more careless, the black parent loses respect, no longer regards tribal authority and, on the whole, is not raised. Dislike for such unions on the part of the community is really based on incompatibilities of racial temperament and social inheritance. While unions between whites and natives are now forbidden, there is no bar to marriage between white and Colored people.

In most Colored families there is evidently great desire to be considered white and for the women to marry white men—sometimes with disastrous consequences when very dark babies are born. Evidence of this trend is afforded by advertisements in Cape Town newspapers of preparations for taking crimp out of hair and of special cosmetics for olive skins. A hopeful feature is that some Colored folk now have stronger views on racial relations and are intermarrying with one another, both appreciating the handicap of their origin. A more stable element in the population is being produced thereby.

Another fact that has often been noted is the bad health and poor physique, especially in the first cross, of the offspring of many racial admixtures in South Africa. Susceptibility to pulmonary complaints, in particular, seems intensified. Bad teeth are extremely common, even in quite young people. Other physical disharmonies, such as large native teeth in small European mouths, small internal organs and deficient circulatory systems in tall Eurafrican men (seen post-mortem), differences in glandular constitution and the like have been noted in many cases. Such conditions produce physical disability, the organisms can not compensate and such individuals are relatively short-lived. Mental disharmony often accompanies the physical and is shown by violent outbursts of temper (often for no apparent reason), personal vanity and sexual instability. Such features are shown by Colored people living in good environments and often on a higher plane than those of the "poor whites," so that environmental factors are not the cause of the manifestations. It seems clear that for both social and physical reasons, white and black are best apart.

The Malays, well known at the Cape, particularly in the Western Province, are reputed generally to keep to themselves, which is all to the good. They make good craftsmen in the building trades and their competence as fishermen has already been mentioned.

Other features, perhaps small now, but bound to be of increasing importance, are the creation of a South African born Eurasian element and of an Afro-Asian admixture. The social status of the Eurasian is usually not a particularly happy one and their position in the community remains to be determined.

Crosses between Indian men and native women occur and in some districts the native women have favored the Indian men more than their own race, a feature resented by the Indian women, in the families of which the natives became members and by the native men, who disliked their women's departure from tribal tradition and control.

The infusion of Chinese blood in certain places among native and Colored peoples, though relatively small, is greater than was at first suspected. In many cases, the Chinese facies seems to have impressed itself upon many of the offspring. The mental characteristics of these hybrids vary, but the Chinese temperament seems to predominate. The native and Colored partners give the Chinese good names as providers, industrious workers and companions. The children certainly show more initiative than native children.

In general, as I have often stated, while intermarriage of black and white is not desirable biologically or socially, yet that does not condemn racial admixture as a whole, for admixture of peoples at similar levels of civilization may result in the perpetuation of highly desirable qualities. In South Africa and other countries where the color problem exists, more attention to the maintenance of racial integrity seems desirable. In South Africa, Colored hybrids tend or did tend to dislike and distrust the parental races on both sides. The best social results seem to accrue, as in the Cape Colored people, when Colored hybrids intermarry among themselves. Mutual respect between races does not necessarily imply social equality. This consideration should be sufficient to prevent such intermarriages as would result in the upset of good traditions and physical, mental and social harmony.

The standard of health of a population is always a matter of paramount importance. Importation of labor from India in the past brought hookworm disease to Natal and Kimberley, and native laborers from Portuguese East Africa have more recently spread hookworm on the gold mines of the Witwatersrand. Industrialization of natives and Colored peoples has led to increased exposure of them to maladies such as tuberculosis, silicosis and pneumonia. They, in turn, have acted as reservoirs of diseases, such as malaria and bilharziasis. How the newer racial strains in the South African population will react in health matters remains to be seen. One thing is certain, both native and Colored need far more instruction in sanitation and in better agricultural methods. These, as well as racial impacts and racial admixture, are subjects for eugenic research.

Fortunately, the need for such eugenic research has been realized. In South Africa since 1920 there has been an active Eugenics and Genetics Committee of the South African Association for the Advancement of Science, which is a member of the International Federation of Eugenic Organizations, and work on racial admixture has been published by the Association. Also, since 1930, there has been a Race Welfare Society in Johannesburg that has maintained a family welfare center for married women, and a center with similar aims is working in Cape Town. These organizations also serve for propaganda on matters pertaining to the maintenance of health, the encouragement of propagation among the better types in the community and the restriction of the same among the less mentally and socially adequate members. The subjects of racial integrity and race admixture are intimately interwoven with the health and prosperity of any nation and must commend themselves to all eugenic organizations.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

FOSSIL FOODS

By Professor RALPH W. CHANEY

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THE question of what to eat is one which has been asked by man and his fellow creatures as long as they have lived upon the earth. Our human ancestors, roaming the hills of northern Asia, primitive horses which ranged over western America, the dinosaur as he lumbered about in the swamps of Alberta—all asked this question. I shall tell you something of the answers of the earth to the insistent demands of its creatures for food. These answers have been recorded in the rocks of distant ages, along with the skeletons of the questioners; they are uncovered by the paleontologist as he journeys back into the past in his search for fossils.

Several weeks ago, in a small town in the mountains of southern Mexico, I passed the hotel kitchen just at the hour that dinner was being prepared. There I saw the cooks grinding corn and meat with an implement called a *metate.* It is a three-legged stone platform with a stone rolling pin—an implement which has been used by primitive people for long ages, in fact, back into the stone age. Seeing this ancient kitchen utensil in use, and later eating the well-cooked food prepared with it, I could almost imagine that I was living back in the days before steel or even wood were used by man, when stone, crudely or cleverly fashioned, furnished the tools for all human activities. I realized, too, that such simply constructed implements limited the possibilities of variety on the menu. Apple pie, or even ham and eggs, could hardly be expected of a stone-age cook.

There is always the possibility, however, that prehistoric cooks might have surprised me. Our Chinese cooks in Mongolia, with the simplest of fuel and with no real ovens, baked enormous chocolate cakes on the birthday anniversaries of members of the Central Asiatic Expedition. What they lacked in equipment, these cooks matched in cleverness. They baked a cake in four sections, using gasoline tins for ovens. Later they spliced the sections together with frosting. The stone-age cooks may have been equally ingenious. In any event, the record of their activities, buried in the cave deposits of northern China, shows how they supplied a vitamin element to the diet of their stone-age families.

Central Asia has come to be considered the home-land, the point of origin, of many of the animals now living upon the earth. When Davidson Black and his Chinese associates found the skulls of Peking Man in the caves of the Western Hills near Peking, China, critical evidence was added to support the theory that the human race also arose in or near that region. In addition to remains of man, they found many bones of horse, deer, rhinoceros and bison. Some of these had been split, others were partly burned. Clearly they represented the remains of animals which had been killed and eaten in the cave homes of Peking Man. We use the word "garbage" for the refuse from our tables, but such a

word may seem inappropriate to the anthropologist and paleontologist, as applied to his choice specimens. A hundred thousand years hence, our garbage may be interesting to future students of man; let us hope they will have a more respectful name for it. In any case, leftovers from the table of Peking Man are the only direct means we have of reconstructing his food habits.

Down in the dark interior of the cave in which he lived are piles of ashes from the fires of this oldest man of Asia. Enough of his skeleton has been found, embedded in the cave deposits, to indicate that Peking Man was a creature able to think and to talk. The crude slivers of quartz left at his fireside show that he had acquired the human habit of using implements to cut or crush his food, and perhaps to scrape the skins which he may have used for clothing. Sifting over the debris of his home, left on the floor of the cave perhaps a million years ago, I found the bones of animals no longer living in northern China, animals which he used for food in the days before game laws limited the size of the hunt. From our present-day knowledge of the importance of plant material in a balanced diet—from the prevalence of spinach weeks, prune festivals and apple-a-day slogans—we might have guessed that without some sort of plant food this early ancestor of ours could not have been sufficiently nourished to prolong the human race; but I did not expect to find the remains of such food since most fruits and vegetables do not have structures which resist decay, as do the bones of animals. Who ever heard of fossil carrots or oranges?

At the end of my stay at Choukoutien, the small town in the Western Hills near Peking where the cave is situated, the Chinese paleontologists in charge of the excavation told me I might select a specimen to take with me. I chose a piece from a large rock-pile lying at the mouth of the cave; fragments of bone and quartz flakes were exposed on its surface. It was a little too large for me to carry, so with my hammer I trimmed off a projecting end. To my surprise, on the broken surface there appeared a round seed the size of a small pea, a seed which I immediately recognized as that of the hackberry. Modern hackberry fruits are something like cherries, but with only a little juice. Hackberry trees grow in many semi-arid parts of America, where birds feed upon their fruits. In the southwest, Indians commonly use them for food. The occurrence of this seed in a mass of rock containing the quartz implements of Peking Man and bone fragments from his meals of long ago seemed of great importance. Here might be a fragment of the oldest plant food known in the human record. But if hackberries had been generally eaten by this early inhabitant of China, there should be more than one of them preserved in his cave. One seed does not make a supper.

A careful search of its walls revealed a layer made up of almost nothing but the broken shells of these fruits. As though they had been crushed in a grinder and thrown aside, there they lay. Were they the food of early man or of some other animal which had lived in the cave? Months later, in my laboratory at the University of California, I answered this question. With the idea that prehistoric squirrels or rats might have carried these seeds into the cave for food and left the shell fragments there, I fed modern hackberry seeds to living rodents. But the squirrels and rats were not interested in such food. Even if they had chewed them, they might have been expected to gnaw off one end of the shell, as a squirrel opens a nut, rather than to break them into fragments like those in the cave. Evidently the fossil hackberries were not brought into the cave and opened by rodents. Then, with one of the quartz implements of Peking Man, I crushed some of the modern seeds. Their shells broke into pieces which were

exactly like the fossil fragments from the cave in China. Modern American Indians grind hackberry seeds on their *metates,* using the juice for flavoring and throwing aside the broken shells. We may suppose that Peking Man, at the very dawn of human history, crushed hackberry seeds with his crude stone tools and secured his vegetable vitamins from the fruits whose broken shells are buried with the bones and implements in the cave deposits at Choukoutien.

Man and his relatives eat a wide variety of foods; but certain animals are almost exclusively vegetarian. Elephants roamed the plains of central Asia a million years or more before Peking Man came to live in the caves of China. They differed from modern elephants in having a long scoop-shovel, formed by the lower jaw and teeth. With such a mouth they could not feed upon leaves in the forest, after the manner of their modern relatives. Rather their jaws seem suited for digging or dredging. Only recently, when Sven Hedin and his expedition crossed Turkestan, there were discovered deposits containing fossil plants which lived at the time these peculiar shovel-tuskers ranged over Asia and into western America. Along with the fossil leaves of poplar and elm, there were found pond-lily leaves and roots, and the stalks of cat-tails and coarse grasses. Here was a source of food for the shovel-tuskers, a type of food still used by the largest American mammal, the moose. Occupying a region too dry for extensive forests, which supply food to most elephants, past and present, they came to depend upon vegetation in lakes and swamps—aquatic vegetation which they shoveled up from the muddy bottoms. With the final drying of these lakes and the disappearance of the water plants, shovel-tusked elephants became extinct.

Changes in food not only have caused races of animals to disappear from the earth in the past, but they have brought about important changes in the animals which survived. The first horses, living in North America more than fifty million years ago, were forest types, browsing the leaves of bushes like sheep or deer. Gradually forests became more restricted, until they occupied only the borders of streams, with grasses covering the plains above. Under these new living conditions, the ancestral horse needed longer legs. Without the protection of the forest, speed was essential for escaping from his enemies and for covering long distances to water. With longer legs and the need for reaching to the ground for grass, a longer neck was required. My friend, Maxim K. Elias, of the Geological Survey of Kansas, has recently found fossil remains of grasses, buried in rocks which also contain the bones of the horses which fed upon them. Grass has in it a hard substance known as silica, which wears the grinding surface of the teeth of animals that eat it. Development of high-crowned teeth was a necessity in view of a changing diet from juicy leaves to hard grass. During long ages horses have increased in size, with longer legs built for speed, and with teeth suited to last a horse's life-time. Because of these changes—because he was able to eat grass, the horse has been able to survive upon the earth, while many other creatures have disappeared.

From the evidence of paleontology, which is a study of the history of life upon the earth, it is apparent that food plays an important part in controlling animal populations. When early man discovered that he could plant grain and secure a large supply of food, he no longer needed to eat hackberry seeds in the dim light of a cave. A cooling and drying climate caused the disappearance of the shovel-tuskers. The spread of grasslands as a result of these same climatic changes has made the modern

horse an efficient running and chewing machine. The earth itself is responsible for the changes in us and in our food.

There is no reason to suppose that earth changes may not take place in the future. Such changes are commonly too slow to be detected in a human lifetime, but over long ages of geologic time they may greatly affect our race. The only method by which we may determine what our food, what we ourselves, may be like in the future, is to survey the changes of the past. By an interpretation of the fossils which were the living creatures of yesterday, by uncovering their foods representing the vegetation of the past, we may come to understand why we eat as we do to-day—what we and our foods may be like in the to-morrow of earth history.

WASTE BY WIND AND WATER

By H. H. BENNETT

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It was not so long ago that enormous dust clouds were rolling out of the Middle West to drop a stifling shroud over the country from the Mississippi Valley to the Atlantic Coast. In June, raging flood waters were bringing havoc to portions of three western states. The first week of July witnessed a tornado in Montana and a cloudburst and flood in New York. Since then Ohio and Wisconsin have experienced record-breaking rains followed by flood waters, and just a short time ago a disastrous hurricane in Florida was accompanied by torrential rains as far north as Maryland. Damage was estimated at millions of dollars.

But the estimates failed to include the most permanent damage of all—the destruction of the soil. Houses and other properties destroyed by the raging waters can be replaced; crops swept out by prairie winds can be replanted. But the fertile soil blown high into the sky or washed by the ton into streams and rivers is lost forever. Spectacular and destructive as these storms are, and as violent and harmful as the floods have been, they do not constitute the really great menace to our soil resources.

The truly tremendous waste is constant. Ruination of the soil is not confined to brief periods when nature exerts the full force of her elements. It proceeds steadily wherever man's cultivation of the land has bared the soil to the wash of descending rain and the sweep of the wind. There is no way of preventing cloudbursts. We have to accept them as they come and hope they will be few and far between. All we can do is attempt to control the floods that often follow.

Dust storms are different. Where cloudbursts are the product of some strange array of nature's elements, dust storms are brought on by man's own misguided failure to protect the soil as he tills it. By simple reasoning, therefore, if he can be guided into the use of practical measures of soil conservation, the cause of the dust storms will be removed. The very nature of these storms has given rise to the popular belief that they are the beginning and the end, the fact and symbol of all soil erosion. This is not true. The gradual washing away of rich topsoil by the runoff of rain-water is far more serious because it is not only constant but wide-spread.

In the work of erosion control, we have come to divide soil erosion into three classes; namely, wind erosion, sheet erosion and gullying. I need only to recall the dust storms to define wind erosion. Sheet erosion is the washing away of a thin layer of topsoil from sloping fields. Gully erosion follows in its wake to cut

deep chasms and ravines which ultimately ruin our fertile fields for cultivation. So we find our country's soil damaged by both wind and water.

Few people realize how tremendously important this land wastage problem really is and how certain it is to affect the permanent welfare of the nation. It is not generally known, for example, that approximately 50 million acres of our erstwhile fertile farm land has been essentially ruined for further practical cultivation; and that another 50 million acres is bordering on this tragic condition.

A nation-wide erosion survey, conducted last year by the Soil Conservation Service, revealed that the extent of damage and ruin to basic farm land far exceeds all prior estimates, and that the 100 million acres so severely impoverished or ruined do not tell the whole sad story. Something like 125 million additional acres, still largely in cultivation, have lost all, or the greater part of their most productive topsoil, with a direct decrease in crop yields that is appalling.

And here, for a moment, I should like to discuss the philosophy which underlies our objective of soil conservation. Right now, as every one knows, agriculture in this country is facing an economic crisis brought on by an accumulation of circumstances in which over-production had a leading rôle. Few people realize, however, that agriculture also faces a physical crisis of tremendous importance to the continuing welfare of this nation.

The remedy for the economic problems which confront the farmer must necessarily be of an economic character. It is, of course, necessary to adjust the total production to the total effective demand. Certainly there is no virtue in producing so much that the price drops to a point which is less than the cost of production. It is never advisable, it can never be wise, to sacrifice productivity. There is nothing incompatible or inconsistent between adjustment of production and conservation of natural resources. For the entire agricultural structure, after all, depends fundamentally upon the physical integrity of the soil. If that physical integrity is depleted at a rate which will see our entire cultivated acreage virtually nonproductive in half a century, there is no alternative for conservation. In other words, while we find it essential to control production, we must at the same time exert every effort to lower production costs, widen markets, improve quality of products and—this is what I wish to stress—maintain our basic resource, the soil. There is a danger, when the country is confronted simultaneously with agricultural crises of an economic and a physical nature, that this distinction may be obscured.

We likewise should remember that thousands of farmers have suffered continuous losses in revenue and are now fighting a losing battle against the poverty which is at least partially the result of extravagant, careless land use, as well as of price declines and maladjustments of the economic balance. If the farm land already ravished and ruined by soil erosion should be divided into 80-acre farms, and restored to its former productiveness, it would be physically capable of supporting no less than 1,250,000 families!

Soil erosion is a serious problem in every one of the 48 states. Naturally, in some states it is more acute than in others. Nebraska, for example, has been affected considerably more than Delaware. Erosion is more prevalent in Texas than it is in Vermont.

Yet we have learned from sad experience that a state comparatively free from erosion this year may be seriously menaced within a decade unless proper care is taken to conserve the soil. Who would have predicted, back in 1925, that the entire Midwest would be so severely hit by dust storms in 1935? Who would

care to predict what will happen in 1945 unless measures to protect the soil are taken at once? As can readily be understood, this is a national problem, which must be met on a national scale. The problem has gone beyond the local stage. It is no longer the concern of the individual farmer whether his land is washed or blown away. The very basis of America's future farming prosperity is at stake and that stake is too high for any but the most profound of considerations. Active leadership by state and federal governments is essential.

So the Soil Conservation Service, one of the youngest of established Federal Service agencies, has been assigned the job of saving our remaining area of good farm land from destructive erosion. It is a sizable commission, but we are moving ahead. The Service proposes to promote farm practices that will protect and conserve the farming lands of the country for permanent agricultural use. Certainly there can be no broad advance or strengthening in the individual farm position; or in upbuilding farm communities, until the land involved is stabilized in relation to soil erosion. In different words, the betterment of economic and social aspects of farm life is closely linked to the solution of the erosion problem.

If the Soil Conservation Service can initiate erosion-control measures on all seriously eroding lands within the next 10 years; if it can secure reasonable control of erosion within the next 20 years; and if it can establish preventive measures on practically all the better lands of the country within the next generation, it will have gone a long way toward solution of the problem. Although the Service has been in existence less than two years, it has already brought an area of approximately 40 million acres under its influence. Plans for expansion will more than double this area at an early date.

We appreciate the gigantic proportions of the task in front of us and are approaching it in all humility. We realize that the job can never be completed successfully without the concerted action, the consistent support and the creative cooperation of the whole people. For, after all, it is primarily and fundamentally a problem of the whole people. The task of conserving the soil is so vast and erosion has already made such headway that the Service could not possibly hope to treat all the land of the country, acre by acre, with necessary measures of erosion control. The job must be done through cooperation between federal and state agencies on the one hand and the farmers and landowners on the other.

The procedure adopted at the outset is one of demonstration. In this way the Service is able to carry its program to the greatest number of farmers with the least expenditure of time and money. As any thinking man will realize, the work of soil conservation must be carried on as economically and quickly as possible.

So, by demonstration, the Service is attempting to show that the impoverishment and destruction of our remaining areas of good agricultural land can be curbed to a very large degree. At the same time it is laying the foundation for a permanent national erosion control program of scope sufficiently broad to meet the acute land crisis created by wasteful methods of land utilization.

As a step toward its goal, the Service has established, or is in the process of establishing, 141 demonstration projects in 41 states, with the average working area for each project limited to approximately 25,000 acres.

Usually a demonstration project comprises all the land within a watershed; that is, all the land lying within the drainage basin of a given stream. Each project area is selected with the most careful consideration of its adaptability to an effective demonstration and its availability for inspection by a large number of farmers. In other words, a

project area must be readily accessible to a great number of farmers and it must present erosion problems that are representative of the entire surrounding countryside. If water erosion is prevalent in the region, the project area must present opportunities to demonstrate how water erosion can be halted. If gullies are numerous around the countryside, work on the project must show how gullies can be controlled.

The farmers of a project area enter into contracts with the government, whereby they agree to operate their farms under guidance of the Soil Conservation Service, to furnish as much labor and material as possible to put the program under way, and to maintain for a five-year period the cropping plans and erosion control structures installed by the Service. In return, the Service agrees to lay out a complete erosion control program for each farm, supervise the work and furnish whatever supplementary labor and material is needed to do a complete job.

Once the Service has placed its control measures in operation, the farmers in the surrounding territory are invited to visit the project and inspect the methods being used. It is hoped in this way to show them just how they themselves can control erosion on their own farms. A demonstration project is in fact a show window.

To-day more than 10,000 farmers have signed formal cooperative contracts, agreeing to carry out for a period of five years the control measures recommended by the erosion specialists as most adaptable to the needs of their lands. Yet the problem of soil erosion extends even further. In addition to the enormous loss incurred by abandoned acres, reduced crops yields and decreased fertility, the country is paying a heavy price for damage to its power and water supply reservoirs, its irrigation systems and its harbors and waterways.

Soil that is valuable on a farm is a menace when it begins to fill up our reservoirs and waterways. The soil washed from farms eventually empties into streams and rivers. Channels that had been deep become shallow. Unable to hold the volume of water within its banks, the river grows wider and wider, overrunning its former boundaries. The possibilities of floods are greatly increased.

Frequently the silt washed from farm lands comes to rest in the bottom of a reservoir. Little by little the reservoir fills up. The capacity is decreased. Millions of invested dollars in the reservoirs are endangered. Social and economic values dependent upon the reservoirs are jeopardized.

The control of erosion is essentially a matter of better land use. It means that we must be more careful—much more careful—of the type of crops we plant, where we plant them and how often we plant them. It means that the day of unintelligent farming is past, just as surely as the day of farming by superstition is past. We have progressed beyond the stage where farmers plant their crops only during certain phases of the moon and harvest accordingly. Farming to-day must be as efficient as a city industry.

The program of the Soil Conservation Service aims primarily at the establishment of agriculture on precisely such a basis of efficiency. Adoption of the program does not mean that production will be impaired. On the contrary, we have already proven that protection of the soil is compatible with production. Our objective is merely to readjust agricultural practice to the needs of the soil.

The realization of that objective is far off. Years of tradition have dictated the farm practices now employed in many of our major agricultural regions. We should be tilting at windmills were we

to attempt an overnight rearrangement of these practices, though, to be sure, we have accomplished almost that in several localities. We must proceed carefully, slowly and thoroughly to convince the farmer that our way is better than the way his father taught him. We must strive to inculcate in his mind a faith in our methods as strong as the faith that links him to the soil. We must instill into the farmers of America that almost reverent attachment for the land which has preserved the agriculture of certain smaller agricultural countries through the centuries.

Ours, certainly, is a goal fully worth the striving. For its attainment will mean that our children, and their children, and their children after them, in truth, "will inherit the earth."

AMERICA BEFORE COLUMBUS

By Dr. H. J. SPINDEN

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If the American Indians had not been living on cultivated crops in most parts of the New World, and if they had not already reached an urban civilization in tropical parts of America before Columbus landed on these western shores, the difference to the European nations who proceeded to conquer the New World would have been very great indeed. They would have found a land rich in natural resources but with none of its plants and animals domesticated. They would have been forced to live on game and wild fruits until such time as they could bring in the domestic plants and animals of the Old World. Their situation would have been like that of England in Australia, for in this southern land the lowly natives had developed none of the indigenous sources of food beyond the hunting and fishing stage. The English colonists had to import all domestic crops, both plant and animal, to assure themselves of food before they even could get started.

But in America the Indians had long since won from the wild a most important series of food plants, including maize, beans, potatoes, sweet potatoes, tomatoes and a long list of other valuable foods as well as other plants having industrial uses. These almost immediately became common property around the world and to-day in the United States the American series of domesticated economic plants makes up well over half of our agricultural wealth.

Now the people who had developed this permanent contribution to world wealth attained in Mexico, Central America and the Andean regions of South America to a high political status, with extensive kingdoms of theocratic type, that is, their rulers were gods or the spokesmen of gods. They had stone-built cities, high expressions of art in architecture, sculpture, metal working and textiles. The Mayas of Yucatan carried astronomy and mathematics to an advanced stage and also invented a kind of hieroglyphic writing which scientists are now attempting to decipher with some slight success. It is perhaps unfortunate that these nations accomplished so little in military science, for the most cultured peoples of America were soon overwhelmed by gunpowder and cold steel. It is not my purpose to draw a moral from the easy conquest of the Aztecs and the Incas by the mailed soldiers of Cortes and Pizarro. Of course, there was no ethical justification for this conquest. But within four hundred years the flag of Spain was again expelled from America and to-day we see the peculiar genius of the red man

imparting flavor and distinction to national life in modern Mexico and modern Peru.

The American Indian is racially related to the tribes of Siberia, and his ancestral culture seems to have been planted in the regions of Lake Baikal and the headwaters of the Yenessei and the Lena Rivers on the southern edge of Siberia somewhere between 2500 and 2000 B.C. This ancestral culture was that of men who hunted and fished in a land of forests and streams. They used polished stone axes of jade and other tough stones, harpoons with detachable bone points, bows and arrows, canoes and paddles, clothing made of sewn skins, baskets, nets, and occasionally made pottery. This culture, which we call Neolithic or New Stone after the polished axe, may have had its beginnings in the Baltic and Scandinavian countries. As the glaciers of the last ice age retreated, forests reoccupied most of the empty land and man entering these forests was able to take up his residence in more and more northerly regions. But, of course, he needed some form of axe in such a forest environment, and it seems he first used parts of reindeer horns for handle and blade as well. On the basis of archeological remains of pre-Neolithic and then of the Neolithic types it has been possible to establish successive northern frontiers of human occupation, first in Germany, then in Denmark and finally in Sweden and Finland.

Now the only available road to the New World lay across the narrow Bering Strait from East Cape in Asia to Cape Prince of Wales in Alaska. This road was located almost precisely at the Arctic Circle and of course it was not revealed till man had pushed his residence well beyond the peninsula of Kamchatka. According to the modern deflated chronology of north European and north Asiatic archeology, the date of the first coming of the red man to America was about 2000 B.C. There is, however, a vociferous American school who would like to have man in America at a much earlier time, say 10,000 B.C., or even 20,000 B.C. if it were possible. The reply which must be made to these is that glacial ice still blocked the northern road at such a remote epoch and that furthermore man in the Old World had not yet attained to the minimum stage of culture disclosed in all parts of America by the most primitive archeological remains.

No example of men of lower type than the present universal species which we call *Homo sapiens* has been discovered in America. Indeed this higher type of human being did not appear in the Old World till the last ice sheet was at its most southern stage, and it took him thousands of years, while the ice was retreating northward, to develop the tools and weapons which became the common heritage of the first American immigrants. Yet it is quite possible that man arrived in what is now territory of our United States, while some large animals now extinct were still living. Fine flint blades, of a peculiar type designed apparently for buffalo lances, have been found in the western plains in association with an extinct and partly fossilized variety of the American bison. Bones of the great ground sloth, and also of camels have been reported in association with fireplaces and other evidences of man's presence. Some have even thought that there were still mammoth in this land when the red man first arrived.

At any rate what a marvelous discovery it was: men, women and children streaming over into Alaska from the easternmost cape of Asia—ascending the Yukon, crossing through the valleys of the Rocky Mountains, following the ranges south with illimitable plains of grass on the eastern horizon. Game was awaiting them, herds of buffalo and antelope, gardens of edible roots and edible fruits. All they had to do was

stream in and occupy, bringing with them their kit of simple tools, their simple arts and ceremonies, their simple forms of government, which nevertheless contained the germs of social cooperations.

Mountain ranges are always the easiest natural roads for animal migrations, and man in America followed the Rockies and the Andes down to Tierra del Fuego. Seacoasts are next, and the Eskimo with a typical seacoast culture followed the shores from Alaska to Greenland. Streams lead through forests and are a third favorite road of primitive man.

Finally the two empty continents were peopled, the weakest tribes being forced into the less desirable regions. Then the more progressive societies attacked the food problem in a practical fashion. They found that by planting seed and spreading water on desert land one could raise crops. So maize was domesticated and soon afterwards beans and other plants. There were few animals to tame for meat diet, but the turkey was tamed and the muskovy duck and besides there were dogs and guinea pigs. Other plants were domesticated for economic uses, including cotton, which now supplies our mills. Tobacco was cultivated as the great medicine capable of inducing a philosophical state of mind. Rubber was manufactured into waterproof capes, into balls for spectacular games, into dolls and was even burned to make black, storm-cloud incense.

Out of the use of leisure saved from the pursuit of food the American Indian nations found they could support kings, priests and artists and build lofty temples on pyramids to satisfy their glory complex.

In the order of development of their civilization there was first the nomadic stage of the first immigrants. Such hunting and fishing tribes survive even to-day in the marginal areas of the far north and the far south. Next the stage of the archaic civilization was developed in arid lands by the first farmers. They delved and spun and made pottery. Thirdly, came the stage of the great wet land cultures, with the Mayas in the van. These began shortly before the time of Christ to show the way to most of the higher arts. But they had no metals, and carved with stone tools. The First Empire of the Mayas closed about 630 A.D. but the influences spread farther and farther afield. It seems there were cultural connections between Central America and Peru in the sixth century A.D. but the influences spread further in the twelfth century, when the Toltecs were in the ascendency. At this time gold and other metals were introduced from South America and metal working was rapidly improved. The rule of the Aztecs in Mexico and the Incas in Peru goes back to about the beginning of the fourteenth century. In the United States area there was a succession of arts, found on several archeological levels in the Southwestern states where the Cliff Dwellers lived and also in the valley of the Mississippi and Ohio Rivers, where the Mound Builders flourished shortly before the discovery of America by Columbus.

And then came the white man with no inhibitions against seizing land and wealth. In a short generation the grandeur that had been Mexico was no more. The daughters of the sun, who wove the finest textiles of the world in Peru, were paying tribute of their handiwork to be sold in the markets of Europe.

But even to-day and in our own United States the Indian comes back, irrepressible, with arts and illusions in his hands to enrich the new American civilizations.

ON THE PERSISTENCE OF USELESSNESS

By Dr. ROBERT A. BUDINGTON

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IN the common New England starfish, *Asterias forbesii*, the extremely short and essentially non-functioning intestine supports an outgrowth termed the rectal coecum. This is generally a minute, bifurcating structure, each branch subdividing into a number, occasionally as many as forty, of small branchlets and excrescences, the whole coecum is hollow, its cavity continuous with that of the intestine No necessary vital function for this organ is known, though it incidentally may augment the respiratory and excretory surfaces in a nearly negligible degree It is essentially useless

The conclusion just stated seems the more tenable because portions of mutilated starfish regenerate, and thrive normally afterward, although lacking this feature of anatomy. Furthermore, assuming the physiology of all five present-day groups of Echinoderms to be somewhat similar, in one as in another, the nonessential character of the starfish rectal coecum is convincingly suggested by its absence in two families of the asteroid class. Only in one order of the Echinoderms, the Holothuria, is a comparable organ active functionally, and in it mainly as a "water-lung" or "respiratory-tree": how actively seems to depend on the thickness and structural accessories of the body-wall

Now, there is nothing unusual in the occurrence, anywhere among animals, of organ remnants, *i.e.*, vestiges, or debris from the evolutionary process, features of the old plans persisting after incomplete adoption of new anatomical patterns of external or internal architecture in consequence of changed external or internal conditions and advantages. Throughout the ageless time while the making of complicated organisms has been going on there have been many instances of style and trend in design; one may playfully employ the terms of ordinary parlance, *e.g.*, archaic, medieval, renascent, Victorian, modern, if he wishes, a difference in application to actual time-periods being understood; and these styles have been more or less copied and now and then mixed in intermediate generations, during the long process of animal and plant devisement and creation. The while these procedures, looking toward "a new day," have been in process, a kind of conservativeness or inertia seems to have compelled the younger progeny not only to accept the general parental formula as to anatomy and physiology, but he has had foisted upon him from the "what-not corner shelves" more or less equipment bequeathed to his family by relatives scattered along many million years of the ancestral trail. The proud human, who rates himself to be quite a novel and "modernized" arrival on the stage of animal society, may correctly reflect that anatomically, physiologically, intellectually, he is scarcely more than a walking museum of "hand-me-downs." His chance for "success" and "distinction" among the intelligentsia, or among prize-fighters, lies, not in any marked newness of his personal components, but mainly in the fact that his particular combination of parts and the results possible thereto has doubtless not occurred before Ecclesiasticus, 1000 B. C., and thus with but a moiety of the mass of evidence before us, precociously and too pessimistically, but with considerable correctness, thought through to the conclusion: "The thing that hath been, it is that which shall be; and that which is done is that which shall be done; and

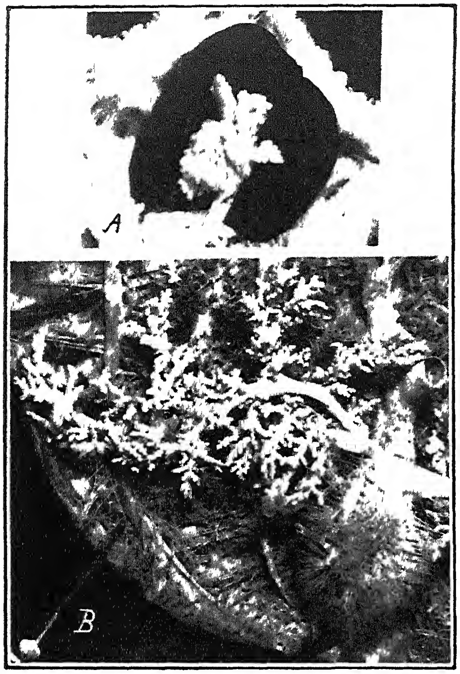


FIG 1. A. RECTAL COECUM OF *Asterıs forbesıı*, THE COMMON NEW ENGLAND STARFISH ENLARGED 4 ×. BLACK PAPER BENEATH THE COECUM. B. CLOACA AND "RESPIRATORY-TREE" OF *Thyone brıareus*, A "SEA-CUCUMBER." THE SEVERED INTESTINE, AMPULLAE OF "TUBE-FEET," AND PORTIONS OF LONGITUDINAL MUSCLES ALSO SHOW. PHOTOGRAPHY BY A. L. PRINCEHORN.

there is no new thing under the sun." Old life materials and their functions have been remodeled or emphasized, often repressed; but most of them were used in some degree even in that early (and present-day) masterpiece, *Amoeba proteus*.

In thus assuming to remark upon an instance of biologıcal uselessness, some one may ask: "Why not deal with some of the eighty and more advertised, dust-covered relics in the human body? Make the matter intimate!" True enough, but even the appendix and tonsils are defended by some as indispensable; and the "high forehead," in spite of the proven uselessness of the cerebral frontal lobes, receives obeisance. Each of these structures, and all others in human anatomy, ıs, of course, a survıval and heritage from "lower" vertebrate ancestors; but for our present thesıs they are of relatıvely small value for the reason, on the one hand, that all vertebrates are very much alike; and furthermore because the prımates are such recent arrivals that we do not yet venture to surmise how long they, as wholes, or theır parts, may maintaın themselves as the future geologıcal eras begın and theır eons pass. We have chosen to look elsewhere for a more persuasive ınstance of persıstent anatomıcal and physiologıcal uselessness; incidentally our case is thereby given argumentative advantage since, ın the popular mind at least, anything in an invertebrate anımal may seem less vital and necessary than most thıngs in vertebrate structure—and consequently their perpetuatıon that much less explıcable.

The general plan of organization for starfishes and all their near relatives, *i.e.*, sea-cucumbers, sea-urchıns, serpent-stars and crinoids, was determined in pre-Cambrian times, *i.e*, before the time when fossılıferous, telltale rocks were laid down Starfishes were already abundant and of numerous specıes before the paleontological family album was installed; since no one knows within a wıde range of centuries how long ago that was, convenience lets us mention a conservative estimate of two hundred mıllion years, half of the guess of some wise men; and the insignificant rectal coecum of the starfish was doubtless in existence and already a relic long before that. How many million years previous to the arrival of the earliest, lowliest vertebrate that was is a matter for further conjecture.

As indicated in the introductory paragraph, the original use of this humble intestinal outgrowth in the starfish physiological economy, or at least in that of its ancestors, seems to have been that of a respiratory organ, and thus doubtless filled and emptied as repeatedly as "breath" was needed. This assumption is made, in the main, because of its simi-

larity in relation to other organs, in its structure and in its behavior to that of a corresponding or homologous structure in the related group of Echinoderms, the Holothurians or sea-cucumbers; and there are reasons aplenty for this assumed relationship. The question, then, is: "In what degree has inheritance from a common ancestor determined that an organ, useless in the animal under discussion, shall resemble a similar organ still essential to and maintaining its original *raison d'être* in another branch of the phylum?"

Four sorts of similarity between the starfish coecum and the cucumber "respiratory-tree" will now be cited, as sufficient illustration of the truth of the contention that nature, in living things, using the instrument of inheritance, does not easily "forget" or "let go", and it is assumed that the cloacal diverticulum in holothurians is a coecum "at its best" First, the star coecum, one two hundredth the volume and weight of a full-grown cucumber "lung," retains, in miniature, the general form of the latter (Fig. 1). Both are branching, dendritic objects, their terminal twigs being rounded bulbs; the diminutive coecum could easily be taken for one of the ends of the numerous branches of the "water-lung." That each is an outgrowth of the terminal section of the food-canal of its respective animal is a simple fundamental fact, itself practically establishing their homology. Thus, even this early, we may at once ask the question, "Why should the starfish have any such unnecessary family appendage fastened upon it?"

On examining the coecum and the "lung" internally, in sections, again their likeness is evident (Fig. 2). Each is hollow (fully expected in the "lung"), and the inner cavity of each is invaded by processes and folds of the lining tissues; vesicular spaces occur in some of these processes; the same tissue layers, though of not the same thickness in both, comprise the walls of each. Thus, although superfluous, the coecum has continued to be made from the same blueprints, little has been forgotten or omitted in all the unmeasured time-eras since the original idea of a rectal diverticulum was adopted.

The retention of plan of structure by an anatomical remnant may seem more easily expected than that any trace of function should at all persist; the former could be more or less perpetuated while function became numbed or nil. As a matter of fact, the star coecum does seem so near "the end of its rope" that its re-

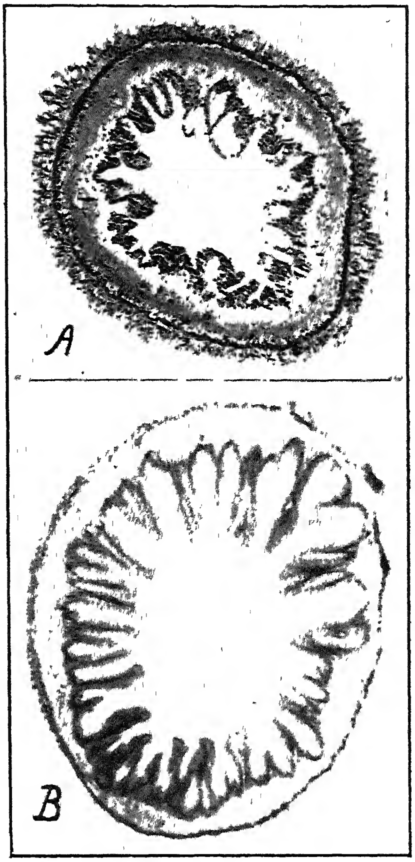


FIG. 2. A. CROSS-SECTION OF A LOBE OF A "RESPIRATORY-TREE." B CROSS-SECTION OF A BRANCH OF A STARFISH RECTAL COECUM THE MUCOSA IN EACH IS DISPOSED IN FOLDS AND PROCESSES; IN THESE VESICULAR SPACES OCCUR. PHOTOMICROGRAPHS; ENLARGEMENT ABOUT 70×.

spiratory rôle is doubtless negligible, if indeed it serves that office at all; and in that respect it fails to match the major usefulness of the "respiratory-tree" Nevertheless, the chemico-physiological studies of such men as Pourtales[1] in 1851, van der Heyde[2] in 1922 and others in the intervening years have demonstrated that the two organs being compared have each some slight excretory function in the ordinary sense of elimination of nitrogenous wastes This "service," though doubtless quite perfunctory as regards the prospering of either the "star" or its cousin "cucumber," does furnish a third evidence of their parallelism; and its non-significance to, but retention by, the asteroid coecum adds further comment on the phenomenon which is being termed "the persistence of uselessness."

A further characteristic of the living rectal coecum of the star, hardly to be anticipated in so vestigial an accessory, is its habit of rhythmic contraction If long ago scrapped as a respiratory instrument, its pulsatile behavior seems inexplicable, save that it continues as an inescapable (as are all inherited items) and unforgettable grandparental procedure which, in this case, may be rated as an imposition. This action-requirement, "wished on" the coecum through millions of centuries and countless generations, makes the traditional visitation of "the sins of the fathers upon the children" through mere integer generations appear little short of simple forgiveness.

The inhalation-exhalation pump-action of sea-cucumbers is, as all familiar with it know, nearly as regular and rhythmic as that of man, and probably for the same reasons. A stop-watch recording of the breathing rate of the cucumber, *Thyone briareus*, for one hour totaled one hundred sixteen "breaths" in that period; a similar watching of the coecum's behavior gave a count of thirty-five for the same period. Perhaps this difference in respiratory frequency could be interpreted as an apparent forgetting by the star if by that is meant that the coecum's use is waning and becoming, contractions and all, a part of its general vestigiality. If analyzed carefully, after their recording by delicately adjusted kymographic apparatus (Fig. 3), numerous details of

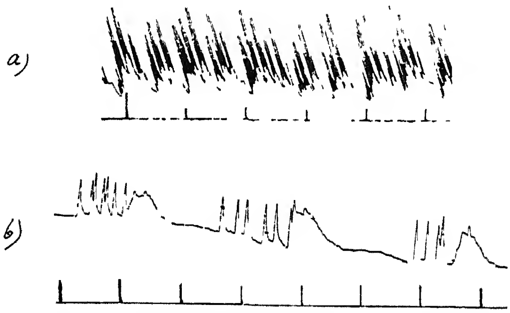


FIG. 3. a. KYMOGRAPH RECORD OF RHYTHMIC CONTRACTIONS OF THE CIRCULAR MUSCLES OF CLOACA OF *Thyone briareus* b SIMILAR KYMOGRAPHIC RECORD OF CONTRACTIONS OF THE STARFISH RECTAL COECUM, *Asterias forbesii*. BOTH CURVES SHOW MARKED PERIODICITY. TIME CURVE IN BOTH, 10-MINUTE INTERVALS.

movement manner prove to be very much the same in both respiratory-tree and coecum; one of these, and the most obvious, a form of hiatus or "sigh," has been hereditarily repeated in both his modern progeny as a legacy from a mutual ancestor's respiratory usage. Just as with the human who normally changes but about 15 per cent of the air in his lungs at each breath, but who occasionally interrupts his breathing pace to take "a deep one" and more thoroughly ventilate his lungs, so too the holothurian breaths occur in groups; and these periods are probably associated with the filling of the extreme end-bulbs of the water-lung, after which the shallower exchange is again resumed until some respiratory shortcoming once more provokes the "sigh." This periodicity in

[1] Pourtales, "On the Holothuriae of the Atlantic Coast of the United States," *Proc. Amer. Assn. Adv. Sci.*, 5th meeting, Washington, 1851.

[2] H. C. van der Heyde, "On the Physiology of Digestion, Respiration, and Excretion in Echinoderms," *C. de Boer, Jr.*, Den Helder, 1922.

the cucumber's breathing doubtless has some significance for it, if not that just suggested; but why should a "habit" of this sort be retained by the starfish coecum? The most plausible assumption which can be made is that this neuromuscular behavior, in the star coecum certainly a genuine idiosyncrasy, is a contracture requirement carried by some innocent chromosome unable and presumably undisposed to shake it off. Each succeeding generation of an incalculable total has unconsciously and unavoidably preserved this strange internal activity, and willed it to the next, even as to details, nearly *ad infinitum.*

Thus has uselessness, resident in specialized protoplasm, persisted; in this instance its abode, the starfish rectal coecum, has run parallel to the holothurian "respiratory-tree" as to four visible and measurable symptoms, external form, inner microscopic anatomy, a barely recognizable function-remnant and pulsatile behavior of a special sort. These items could be analyzed more at length with profit, but such elaboration is not necessary for a conclusion. "Stars" and "cucumbers" are unquestionably progeny of a one-time mutual parent which breathed by means of an intestinal diverticulum; such ancestor throve so long before the Cambrian period that it already had descendants, before that period began, as divergent as these cousins n-times removed; and one does not venture to guess how many ages or generations were used up in establishing that early divergence. As having some bearing on the point we may reflect that not much change in either line has taken place in the two hundred million years of which we have some knowledge

The alert watch for anatomical and physiological change, with the possible birth of new species through mutation, has occupied the spotlight center on the stage of biological research, estimate and reflection for the last thirty years. This search has been so dominant in laboratory and literature that the phenomena of permanence have all but escaped attention, assuredly have elicited little expressed wonder. Constancy, reliability —these are so normal to nature's procedure as to be practically overlooked; nevertheless, this tenacity, this insistence, this never-lapsing memory of nature as heredity weaves its patterns repeatedly through millenniums of time is indescribably impressive even when any normal organ of everyday use is considered; and yet more so when an apparently valueless structure is incorporated in each of hundreds of millions of generations through successive geologic ages. This is one of the numerous biological phenomena which give us pause and induces the quiet, reflective mood; the inheritance carriers are incalculably stable in their effects so long as they themselves are not modified in any manner and can have their way.

Nature's plasticity gives hope; her constancy, dependability and tenacity, when recognized and assimilated, contribute to confidence and equilibrium of spirit; and a consciousness of both is vital to what we call intellectual and spiritual poise in living. Evolution has occurred in consequence of organic modifiability, and as a process is so far accepted in the premises of all the thinking of men that nature's continual adjustments seem a part of simple normality; in regrettable contrast, her uniformity and steadiness are so commonplace and primary as to become almost lost to our awareness. Indeed, it takes a poet to express as well as to be cognizant of this truth; and Lucretius it was who, nearly nineteen hundred years ago, sensed it clearly and proclaimed it in these words:

> Things throughout proceed
> In firm and devious order, and maintain
> To Nature true their fixt generic stamp.

—*Photograph by Bachrach*

PROFESSOR EDWIN G. CONKLIN

THE PROGRESS OF SCIENCE

PROFESSOR EDWIN G. CONKLIN, PRESIDENT OF THE AMERICAN ASSOCIATION

THE biologists of the country were greatly honored and the American Association for the Advancement of Science well served by the election of Dr. Edwin G. Conklin, of Princeton University, to the presidency of the association. He brings to the office a ripe experience in scientific organizations, a wide personal acquaintance among scientists of all kinds and a seasoned judgment of men and affairs. In addition to his high scientific achievements, Professor Conklin is one of our most able and pleasing public speakers and should be able to advance greatly the purpose of the association to bring its work authoritatively and convincingly before the public.

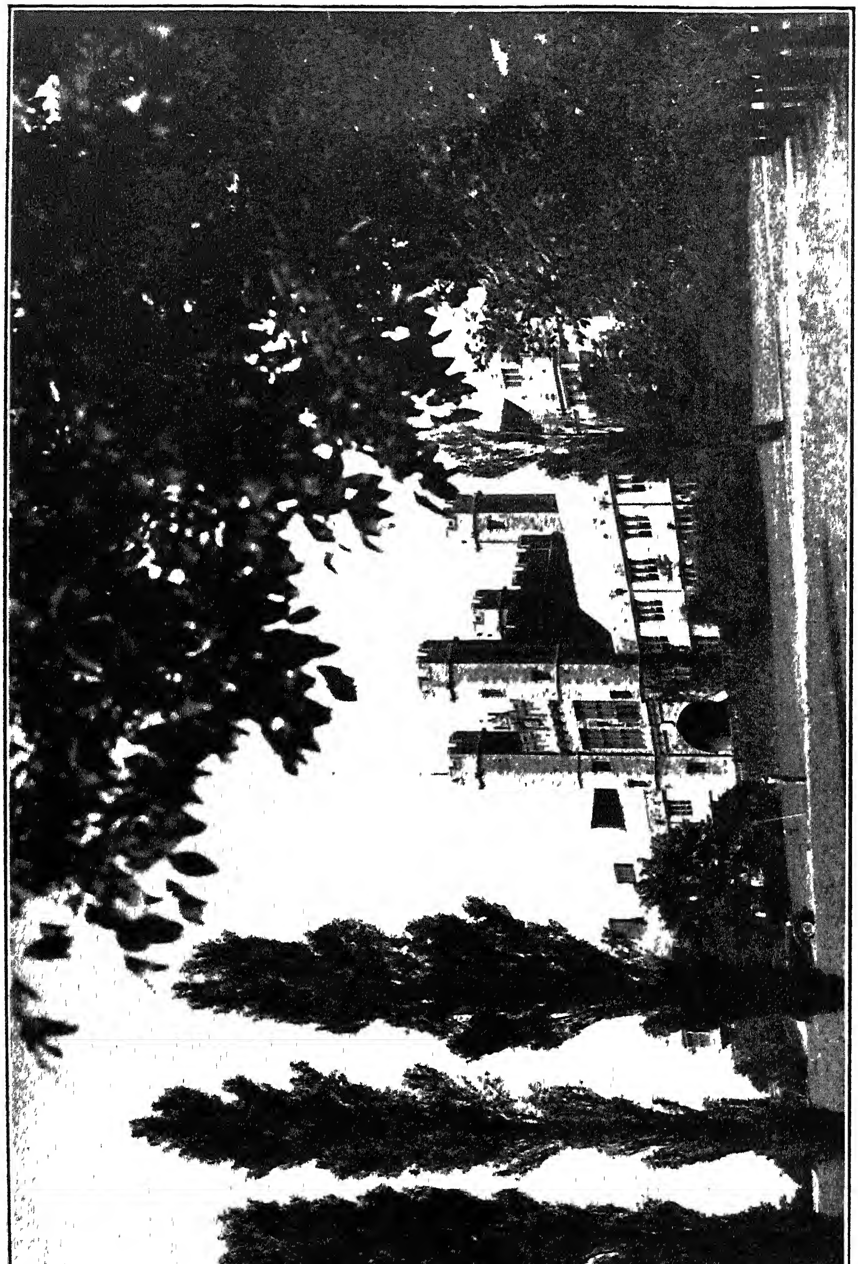
Since its beginning, Dr. Conklin has been active and influential in the management of that unique institution, the Marine Biological Laboratory at Woods Hole. More recently he has, as president of the board of trustees, been able to secure the permanent and effective organization of the Bermuda Biological Station, an international undertaking. As chairman of the committee on grants of the American Philosophical Society and as one of its vice-presidents, he does much to further the work of this ancient and honorable institution.

Among other important connections, Dr Conklin is one of the original members of the advisory board of the Wistar Institute, and a trustee of the Woods Hole Oceanographic Institute At one time or another he has been president of each of the various biological organizations to which he belongs. In every instance, Professor Conklin brings a devotion and a competency which greatly profit the affairs of the scientific group which he serves.

In the matter of scientific publication he has been connected with the *Journal of Morphology*, *Journal of Experimental Zoology*, *Genetics* and the *Biological Bulletin*, and was chairman of a committee of the National Academy appointed to study the general question of publications devoted to biological research

Professor Conklin's own investigations have centered about problems of development, differentiation and phylogeny. In the course of these he has made extensive studies in the embryology of Gasteropods, Tunicates, Coelenterates, Brachiopods and Amphioxus. The study of development led naturally to inquiries into the mechanism of cell reproduction and growth and eventually into the relations between members of a genetic series. He has always been concerned with the philosophical implications of biological studies and has participated actively in public discussion of evolutionary theories. Particularly has he been concerned with the implications of biological facts and theories in human affairs. While Professor Conklin's studies have ranged rather widely, they are always characterized by great care, precision and judgment. Others of his contemporaries have published more papers, but there are few who have contributed more sound and enduring pages to biological literature. The qualities of mind and character which mark his scientific work will certainly be reflected to advantage in his conduct of the affairs of the American Association for the Advancement of Science.

C. E. McCLUNG



ROBERT S. BROOKINGS HALL, THE ADMINISTRATION BUILDING OF WASHINGTON UNIVERSITY

THE AMERICAN ASSOCIATION AT ST. LOUIS

St Louis in some mysterious way seems to furnish just the proper background for meetings of unusual importance from the point of view of scientific progress. At the association's first meeting in that city, held in August, 1878, Thomas Alva Edison read a paper on the use of the tasimeter for measuring the heat of the stars and the sun's corona, and another on the sonorous or bubble voltameter, and Albert A. Michelson described his experimental determination of the velocity of light. Five important papers on entomological subjects were read by Charles V. Riley, and a description of a human skull recently discovered in a gravel bed in Colorado was contributed by Thomas Belt of London, well known for his description of the animals and plants of Nicaragua.

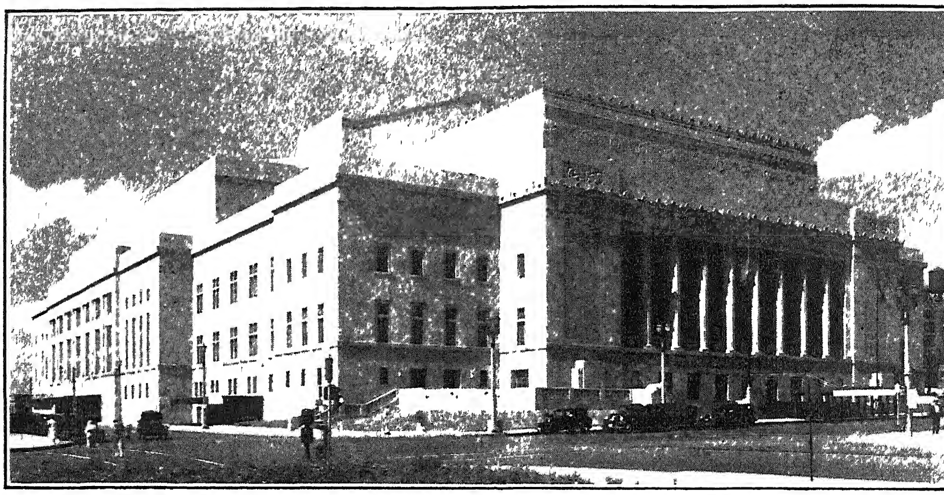
These important papers were read while an epidemic of yellow fever was raging in the country to the southward and threatening at any time to reach St. Louis. That dread disease is now only a memory in the United States. Its elimination was made possible by the combined work of physicians, engineers and entomologists, aided by vast improvement in communications. Riley and Edison and others present at the first meeting both directly and through the stimulus of their work and its effect on others played an important part in making St. Louis the healthful and delightful city that it is to-day.

No less important than these early contributions were many that were made at the recent meeting. At present we are unable clearly to foresee their full significance We feel that progress has been made—indeed, we know it has. But it takes time to allocate these new discoveries and deductions and properly to appraise them in the light of related facts and inferences, some still to be worked out. As an illustration, three papers on certain relations between synthetic growth substances and plants by Drs P. W. Zimmerman and A. E. Hitchcock were especially outstanding. Their implications are far-reaching. These papers were awarded the association's $1,000 prize. But a number of other papers were almost equally outstanding Seldom at any meeting have there been so many papers that gave promise of great things to come.

The papers and addresses of the regular program were supplemented by radio talks by some of the nation's leading scientific men. Three of these reached a nation-wide audience over the National Broadcasting Company and Columbia networks, while others were given from stations WEW, KSD, WTMV and KWK. By means of the radio many thousands of people unable to attend the meeting were made aware of the onward march of science.

Radio talks and papers were not the only features of the meeting. The exhibit was unusually extensive and attractive, covering in more or less detail nearly every line of science, pure and applied, and including scientific apparatus and the latest and most authoritative books. No less than seventy-one exhibits were listed in the program. While naturally each exhibit had its own appeal for a special group, most of the exhibits were of interest to all, regardless of their personal preferences. Most attractive to the general public was the exhibit prepared by the Federal Bureau of Investigation of the United States Department of Justice, in which was shown the application of science in many different forms to the tracking down of criminals and the establishment of guilt.

No matter how diversified the program or how efficient the planning of a meeting, there is always something lacking unless the setting is harmonious. In St. Louis those from other cities in attendance were made to feel that they were



THE MUNICIPAL AUDITORIUM IN ST LOUIS
REGISTRATION HEADQUARTERS AND THE SCIENCE EXHIBITION WERE LOCATED IN THIS BUILDING.

in a thoroughly sympathetic atmosphere The people of St. Louis proved to be most delightful hosts, and their hospitality went a long way toward making the meeting one of the most pleasant, as it was one of the most profitable, in the history of the association. The association left St. Louis with the hope that it will not be very many years before they again will have the pleasure of foregathering in that congenial city

The association and its affiliated and associated societies appreciate the aid given in making this St. Louis meeting a success. Especial thanks are due to Washington University, St. Louis University, the Academy of Sciences of St. Louis, the Board of Estimate and Apportionment of the City of St Louis and the Municipal Auditorium Commission of the City of St. Louis Special thanks are due to the members of the local committee, who handled so efficiently the numerous and arduous tasks involved in making the preparations for so large a meeting, and to the many laboratories and commercial organizations for the excellent exhibits that assured the success of the Science Exhibition.

AUSTIN H. CLARK

RECENT WORK ON COSMIC RAYS

DR. ARTHUR H. COMPTON, of the University of Chicago, who shared the Nobel prize in 1927, summarized recent work on cosmic rays carried out in his own and in other laboratories before a joint session at St. Louis of the section of physics of the American Association for the Advancement of Science, the American Physical Society and the American Association of Physics Teachers.

Dr. Compton stated that cosmic rays are truly "cosmic" in that they probably emanate from remote galaxies or remote space The primary cosmic rays, particles as distinct from secondary rays or the disintegration products caused when the rays strike earth's atmosphere, have energies ranging from two billion electron-volts to sixty billion electron-volts, and in occasional bursts, particles occur with energies as high as six hundred billion electron-volts. Their total heat at earth, however, is probably no greater than that of starlight

A provisional analysis of the components of the rays furnished adequate evi-

dence that the primary cosmic rays are in fact electrically charged particles The most prominent part of the primary cosmic rays observed above sea-level consists of nearly equal parts of positive and negative electrons. At sea level and below is a very penetrating component for which the identification as protons seems to be required. At very high altitudes there appears a relatively absorbable component, which seems to consist of alpha particles.

The conclusion that cosmic rays are largely electrically charged particles is based chiefly on the "latitude effect" observed in cosmic rays studies. Observations taken throughout the world, among them records of intensity taken at more than 100 stations by some eighty investigators working under the direction of Dr. Compton in 1931–34, show that the rays are affected by the earth's magnetic field. At ordinary altitudes the rays are some 16 per cent. more intense near the magnetic poles than they are near the magnetic equator. At higher altitudes, where the intensity is greater, the ratio of intensities between the poles and the equator is probably more than 100 to 1. Photons, or true rays, would not be so deflected by the earth's magnetic field.

Curve lines of equal cosmic ray intensity follow closely the parallels of geomagnetic latitude, and follow also the lines of frequency of occurrence of auroral displays, which means that the aurora and the cosmic rays are affected by the earth's magnetism in the same manner The lower intensity of equatorial cosmic rays in the eastern hemisphere than in the western hemisphere corresponds to the stronger magnetic field of the earth in the east.

Dr. Compton showed a new world-map showing "isocosms" or curves of uniform cosmic ray intensities. More exhaustive analysis of this and other data led to the tentative identification of cosmic ray components through a procedure described as "using the earth as a huge though crude magnetic spectrograph", the earth itself acts as the magnet and in place of the electric field we have the stopping power of the earth's atmosphere.

The conclusion that the rays originate far outside the earth, the sun or the Milky Way is based on the fact that they apparently approach the earth uniformly from all directions. Dr. Compton stated that outside the earth's atmosphere we fail to find any isotropic distribution of matter within our galaxy where such rays might originate The extra-galactic nebulae, or space itself, would, on the other hand, satisfy the condition of spherical symmetry. He suggested that most of them originate at an effective distance of between one billion and ten billion light years

There appears to be an effect on the observed intensity of cosmic rays due to the rotation of the Milky Way. According to astronomers this rotation carries us toward about 47 degrees north and right ascension 20 hr. 55 min. at a speed of about 300 kilometers a second. This should cause a diurnal variation in cosmic ray intensity, following sidereal time, through a range of the order of about 0 1 per cent Apparently there is such a variation

Efforts to learn how cosmic rays are produced have been unsuccessful. Among the more plausible theories are Lemaître's that they are "super-radioactive particles" emitted at the initial explosion of the expanding universe; Swann's that they are electrons accelerated by electromagnetic induction from the changing magnetic field of "sunspots" on giant stars, and Milne's that they owe their energies to the gravitational attraction of the universe.

In conclusion Dr. Compton pointed out that cosmic rays should prove an extremely useful tool. The immense individual energies of these rays, some of them with an erg of energy for a single atomic projectile, give them a unique

place in the physicist's atomic artillery Already they have been used in the discovery of positrons They will be used to extend knowledge of the earth's magnetic field high above the atmosphere; to test electrodynamics in an energy region heretofore inaccessible; and in astronomy, as a powerful means of studying the rotation of the galaxy and of learning the ancient history of the universe. In biology, it is not impossible that they play an important part in the spontaneous variations upon which evolutionary changes depend

One perplexing recent problem is that the high-energy cosmic ray particles do not excite as much radiation as is required by present electrical theory. An extension of the present theory of electrodynamics is needed, comparable with the extension of Maxwell's electrodynamics introduced by Lorentz and Einstein for the condition of high velocities.

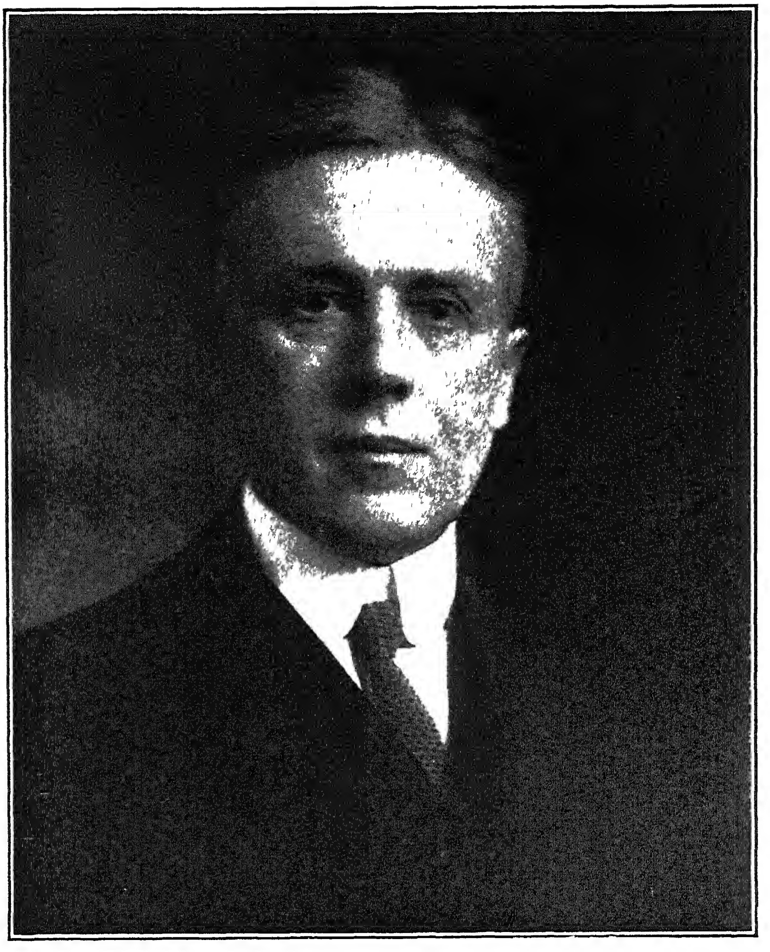
CORRESPONDENT

THE AWARD OF THE PENROSE MEDAL TO PROFESSOR DALY

AT the annual meeting of the Geological Society of America, held at the Waldorf-Astoria, New York, on December 26, 27 and 28, the eighth presentation of the Penrose Medal was made to Professor Reginald Aldworth Daly, Sturgis-Hooper professor of geology at Harvard University This medal, which was established on March 4, 1927, by the late Richard Alexander Fullerton Penrose, Jr., is awarded, under the terms of the deed of gift, "in recognition of eminent research in pure geology" and "of outstanding original contributions or achievements which mark a decided advance in the science of geology." Former recipients of the medal are Thomas Chrowder Chamberlin, 1927; Jakob Johannes Sederholm, 1928; Francois Alfred Antoine Lacroix, 1930; William Morris Davis, 1931, Edward Oscar Ulrich, 1932; Waldemar Lindgren, 1933; Charles Schuchert, 1934.

Professor Daly is a Canadian by birth, having been born at Napanee, Ontario, on May 19, 1871. He received his A.B. at Victoria University, Toronto, in 1891, and then went to Harvard, where he received the A.M. degree in 1893 and Ph.D. in 1896. He then studied at Heidelberg and Paris. From 1901 to 1907 he was with the Geological Survey of Canada, and in 1907 became professor of physical geology at the Massachusetts Institute of Technology, which position he held until 1912, when he became Sturgis-Hooper professor of geology at Harvard. He has been honored with the doctor of science degree from the University of Toronto and with the Hayden Medal of the Philadelphia Academy of Natural Sciences In 1932 he was president of the Geological Society of America

"Although Daly is generally thought of as primarily a petrologist, he has, in fact, made many brilliant contributions in the most widely separated fields of geology," said the committee of award. "His writings now exceed a hundred titles, and indicate clearly the remarkably wide range of his interests Gifted, too, with an extraordinarily fertile scientific imagination, he has, nevertheless, at no time hesitated to do detailed work of the most painstaking kind. This capacity made itself apparent in one of his earliest writings, 'On the optical characters of the vertical zone of amphiboles and pyroxenes; and on a new method of determining the extinction angles of these minerals by means of cleavage pieces.' It is most conspicuously shown in his work in obtaining the average composition of the various igneous rocks, 1,935 of them, which involved a worldwide scrutiny of the literature, assembling of the analyses, and averaging them. Merely the assembling of 547 analyses of granites from the world's literature, let alone averaging them, be-



PROFESSOR REGINALD ALDWORTH DALY

speaks an extraordinary capacity for hard work.

"Professor Daly's contributions in the field of igneous geology and petrology are too well known to need repetition; in these fields, he is an acknowledged world leader. Many of his ideas have become parts of the body of our science. . . . In addition he has made great and stimulating contributions to physiography, geophysics, volcanology, seismology, coral reef problems and glacial geology."

The presentation was made by Professor Nevin M. Fenneman, head of the department of geology at the University of Cincinnati and retiring president of the Geological Society of America, at the banquet held in connection with the forty-eighth annual meeting of the society.

CHARLES P. BERKEY

PROFESSOR HANS SPEMANN, NOBEL LAUREATE IN PHYSIOLOGY AND MEDICINE

On October 24 last the Nobel Prize in Physiology and Medicine for 1935 was awarded to Hans Spemann, professor of zoology and director of the Zoological Institute of the University of Freiburg, Germany. He was born in Stuttgart in

irrevocably determined, as was proved by exchanging transplants of presumptive neural plate and presumptive epidermis when the former becomes ordinary epidermis and the latter neural plate. But when a portion of the dorsal lip of the gastrula is transplanted to another region it does not follow the development of neighboring parts but forces neighboring parts to follow it. "It organizes its new surroundings and gives origin to a secondary embryo." Hence the region of the dorsal lip of the gastrula was called the "center of organization" and its cells or materials "organizers." More detailed experiments showed that there are "head organizers" and "trunk organizers," which occupy specific positions in the dorsal lip. These organizers evidently act as the optic cup does in inducing alien epidermis to form a lens, and Spemann has suggested that they might better be called "inductors" rather than "organizers," especially since it has been found that dead cells and dried and crushed material from the dorsal lip will induce embryo formation wherever they are implanted. Work on the nature of the "organizer" or "inductor" is going on in many laboratories and it is too early to express a definite opinion on this subject, but to have found that there is a definite region of the embryo which leads in differentiation is a major discovery and it was specifically for this that the Nobel award was made. Spemann poses the question whether the whole course of development is a series of inductions of one part after another in the nature of a "chain reaction." If so, it is purely epigenetic, but on the other hand phenomena of "double assurance" seem to speak against so simple a process.

Spemann is not a hard-boiled mechanist, he offers no absurdly simple explanations of one of the most complex phenomena in all nature. On the contrary, he recognizes the profound and perplexing nature of embryonic development. In his rectorial address at the University of Freiburg in 1923 he said: "Nature acts in development as an artist making a picture or model, indeed as every organizer does who handles materials whether living or not living. . . . This differs from Weismann's purely mechanistic theories and resembles our own activities." And in an address at the Marine Biological Laboratory in Woods Hole in 1931 he closed by saying: "It is my personal conviction that the processes going on in the living matter may be compared with nothing else so well as with the workings of our own mind. To deal with the living organism as if it were animated unto its last fibers seems to me the best way to understand it."

The fundamental character of Spemann's researches has been widely recognized. He was chosen rector of the University of Freiburg in 1923, was Croonian lecturer before the Royal Society of London in 1927, and Silliman lecturer at Yale University in 1933. He is a member of many scientific and learned societies in Europe and is a foreign associate of our own National Academy of Sciences. His modest, sincere and kindly nature have endeared him to a multitude of friends who rejoice in this latest and greatest honor which has been conferred upon him.

EDWIN G. CONKLIN

THE SCIENTIFIC MONTHLY

MARCH, 1936

THE PLANT LIFE OF THE SONORAN DESERT

By Dr. FORREST SHREVE

DESERT LABORATORY OF THE CARNEGIE INSTITUTION OF WASHINGTON

For thousands of years the human race has shown a strong liking for the desert. Important steps in our early civilization were made by the people of the arid lands of southwestern Asia. For many centuries the nations that were dominant in human progress held sway over territory that is mainly desert or semi-desert. In Arabia and around the edges of the Sahara can still be found people living under adjustments to desert conditions that were made over four thousand years ago. Before the seventh century of the Christian era no important cultures developed in the wooded and rainy parts of the Old World. When America was discovered, its highest civilizations were found not in the Mississippi Valley or the Valley of the Amazon but in the arid plateaus of Mexico and Peru. Early men seem to have preferred to live in the open country wherever living was possible.

Desert Limitations

The life of primitive desert people is led in a state of precise adjustment to their uncongenial and immutable environment. The advances which they are able to make are closely controlled by these adjustments. They are vitally dependent on water supply, arable soil or forage for their animals. Under such conditions environment controls the distribution and abundance of man as sharply as it does of plants.

The events which led the political dominance of the world out of the Mediterranean region into cooler and moister western Europe at the same time liberated the march of our material advancement from the limitations that the meager resources of the desert had placed upon it. It is very certain that if the course of our civilization had been run solely in the desert regions in which it began we would be very far behind our present stage of advancement.

The thorough exploration of the world, the settlement of new lands and the rapid growth of population have again brought us to the edge of the desert, not looking out at more promising lands but looking in and appraising it as a place to live. It is one of the last unoccupied lands, one of the last outlets for the growing masses of humanity.

Civilized man has already begun to go back into the desert. In South Africa and Australia the frontiers have been gradually pushed out into regions once regarded as uninhabitable. In the United States for the last thirty years there has been a slackening in the growth of population in some of the northeastern states and a steady growth in those states which have little rain and much sunshine

The desert settler of to-day has countless advantages over the ancients and innumerable contrivances that help in the adjustment of his more exacting life to

the same group of inexorable conditions that will always be the desert To what extent will the settler be able to utilize the desert? What factors will limit his activities? How permanent will his efforts be? Can his life in the desert be made rich, full and happy or will it be meager, anxious and bare? There are many uncertainties involved in the answers to these questions, but we may be very sure that whatever success he achieves will depend chiefly upon his knowledge of the desert. To this the scientific man can hope to make many valuable contributions.

Concept of Desert

Desert is not a simple concept in any of its physical or biological aspects Examples of it range from the nearly barren sands of the Sahara and the Gobi, through the alkaline plains of Nevada and the Kalahari to the relatively green slopes of Tehuacan or the Karroo. Rainfall, temperature, amount of cloudiness and wind are all unlike from desert to desert Geological structure, physiographic development and mineralogical and soil character all add further variety to the scattered desert and semi-desert regions which form one fifth of the land surface of the earth.

An adequate definition of desert must be based on a group of characteristics rather than a single one. Deficient and uncertain rainfall is the basic feature, but it may vary from almost nothing to more than twenty inches. It is only in tropical latitudes that the latter amount is found, supporting there a vegetation much like that which grows with ten inches of rain in temperate latitudes. The biologist regards as desert all those areas in which deficient rainfall and all its consequences have made a strong impression on the structure, functions and behavior of living things. The Standard Dictionary defines desert as a place where irrigation is essential to permanent occupation. This, of course, is merely an expression of the principal consequence of desert conditions from a homocentric view-point.

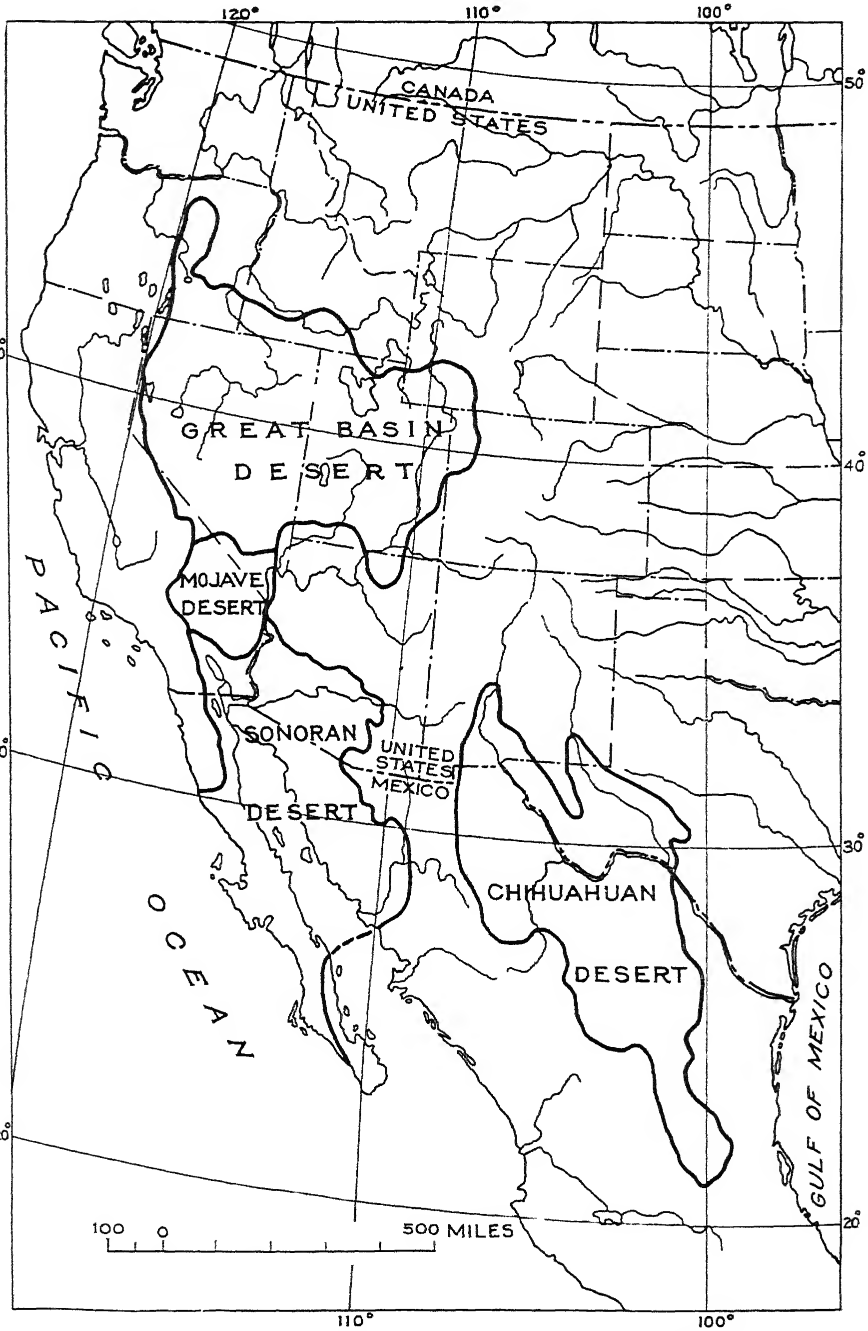
Deserts of the World

A glance at a map of the world on which the large desert areas are shown reveals their extent, their position just outside the tropical zone and their isolation from each other. The largest and most arid area is the one which extends from the Atlantic coast of Africa through Egypt and Asia Minor eastward nearly across Asia. Large arid and semi-arid areas exist in South Africa, and the major part of Australia is desert. In the western hemisphere there are deserts in both North and South America, much smaller than those of the eastern hemisphere but exhibiting an equally wide range from extreme aridity to semi-arid areas or transitions to grassland or thorn-forest.

In each of the six large deserts the plant life is distinct from that of the surrounding regions and distinct from that of the other deserts There is a slight relationship between South Africa and Australia and also between North and South America. At the same time that the species of plants in the deserts are distinct, it has been found that the majority belong to genera found elsewhere and nearly all of them to families which are either richly or poorly represented outside the desert The lack of strong relationship between the plants of the six great deserts indicates that their isolation from one another has given each of them a separate history Also, the generic and family relationships of the plants to those of moister places demonstrates that each of the deserts has derived its plants from adjacent regions of more favorable climate.

Effect of Desert on Plants

Great interest attaches to the genera and especially the families of plants which are confined, or even nearly con-



MAP SHOWING THE DESERT AREAS OF NORTH AMERICA.

fined to the desert. They are the living representatives of the races of plants which have undergone the greatest change in entering the desert and in acquiring all the characteristics that have made possible their survival and success. We see that the evolutionary development which has accompanied entry into regions of aridity and brilliant sunshine has in many cases been so far-reaching as to effect the flower, fruit, seed, woody tissues and other features on which our conceptions of plant relationship are based. In a far greater number of cases the plants which have entered the desert have only undergone modification of the root, stem, leaf and other vegetative structures Some of these changes have been so profound as to make the appearance of the plant wholly unlike that of its nearest relatives of the savanna or forest, yet the flowers and fruit are almost unchanged.

In any effort to understand the development of the plants of the desert it is important to learn as much as possible about their origin and the history of their descent, and also to know fully their structure, physiological behavior, life history from seed to adult and relationships to climate and soil. It must be kept in mind that the plant is both a genetic entity and a physiological entity, that it is both a descendant and an independent individual Characters inherited from ancestors of high moisture requirement have been reduced and transformed by the evolutionary processes which have accompanied the settlement of the desert by plants. We have before us for study both the history of these processes and their end results in the plants of to-day. The history must be compiled from bits of evidence of every pertinent kind. The end results are to be found by investigation of the plants which have stood the test of adjusting themselves to new conditions or to new localities in which the same conditions have long persisted.

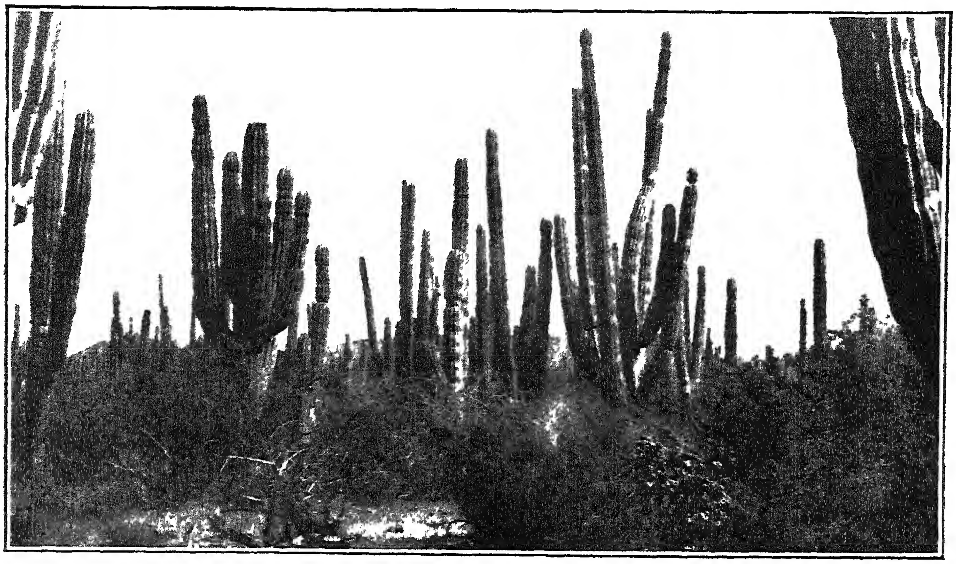
American Deserts

For over thirty years work on desert plants and the conditions which they encounter has been conducted by the Carnegie Institution at the Desert Laboratory, located near Tucson, Arizona. There have been two or three resident investigators at the laboratory throughout its operation, and numerous visiting investigators have worked there from time to time for short periods The work of the laboratory has done much to increase our knowledge of the desert and of the plant life of the surrounding region

The desert region of North America extends from eastern Oregon to the Mexican state of Puebla and from the Pacific coast of Baja California to the valley of Devil's River in Texas. It is separated into two parts by the high plains along the continental divide and by the Sierra Madre of northwestern Mexico The Chihuahuan Desert, forming the eastern part, is poorly known from the botanical standpoint. The western part falls rather naturally into three areas, which differ in altitude, physiographic features and climate, as well as in plant and animal life These areas are the Great Basin, the Mojave Desert and the Sonoran Desert. All four of the subdivisions of the North American Desert have received some attention at the hands of investigators at the Desert Laboratory. The work has been chiefly, however, in southern Arizona, extending in recent years to the entire Sonoran Desert.

Types of Desert Plants

We have seen that in America, as well as in the Old World, the desert is characterized by distinct species and by plants of unusual structure and behavior. Also, there are certain features in the make-up of the natural communities of plants which do much to lend character to the desert landscape. The most casual observer will note that desert



THE MASSIVE *PACHYCEREUS PRINGLEI*
REACHES ITS MAXIMUM DENSITY AT THE HEAD OF CONCEPCION BAY, BAJA CALIFORNIA.

plants are widely spaced, often leaving much bare ground, and that their height is less than that of hardwood or coniferous forest trees. Both of these features are to be explained by the scanty water supply. Another commonly observed feature of desert vegetation is the mingling of plants which differ greatly in size, form, manner of branching and method of exposing their green surfaces. This heterogeneity is much more in evidence in the Sonoran and Chihuahuan Deserts than it is in the Mojave or the Great Basin. It is, in fact, a feature of the warmer deserts and does much to augment their biological interest. Where such heterogeneity exists it is an indication of the numerous ways in which evolutionary development has worked out solutions for the problem of life in the desert.

An analysis of these solutions reveals three main classes, represented by the short-lived or ephemeral plants, the succulent and the non-succulent ones. The ephemerals are scarcely desert plants in their anatomy or physiology, since they appear only in the rainy seasons and wholly escape the difficulties of the critical months of the year. In one important respect they show remarkable fitness for their place in nature. With the sudden arrival of favorable conditions—a moist soil of the proper temperature—their seeds germinate promptly and they grow with astonishing speed. In many species only five weeks elapse from germination to the maturing of a new crop of seeds. The duration of the rainy period determines whether such a plant reaches a height of one inch and produces one flower or whether it grows to eighteen or twenty inches and matures a thousand seeds.

The succulent group is mainly represented by the cacti in America and by the Euphorbias in South Africa. In the other large deserts the succulent is a very rare type, although in North Africa and Australia the cactus has been introduced from America and has flourished. In these plants the leaf has been dispensed with and its work has been taken over by the green tissue which clothes the

stem [illegible] the stem has undergone enlargement through the development of great masses of tissue in which an accumulation of water is held The root system of the cactus is widely distributed near the surface of the ground When rain wets the uppermost layers of soil the plant quickly renews its water content, perhaps badly depleted by many rainless months.

The non-succulent perennial plants are active throughout the year or else throughout the frostless season Their water supply must be renewed daily and survival depends on a deep root system, widely distributed through the lower levels of the soil, in which a modicum of moisture persists throughout the year.

In brief, the ephemeral plants escape the rigors of a dry climate, the succulents have a mechanism which equalizes the irregularity of water supply, and the non-succulents have the daily problem of maintaining equality between their water loss and water supply. Each of these three types of adjustment to desert conditions is found in hundreds of species, and the three types grow side by side in the vegetation.

In a closer study of the great array of forms found in the warmer and less extreme deserts the three main types of plants that have been mentioned may be subdivided many times.

Ephemeral Plants

Although the ephemeral plants do not show any outstanding features of structure they have nevertheless many minor peculiarities of habit, branching and leaf anatomy which appear to be of importance in their brief lives and to aid them in making the maximum use of the last residue of moisture in a rapidly drying soil. There are great differences in the relative abundance of the numerous species from year to year, which has been found to depend upon whether the rains come early or late, in a few heavy storms or many light ones, and whether there is much or little cloudiness Their relative size and abundance over a given area furnish an accurate index of the amount of moisture in the soil and of the conditions for evaporation. The slightly shaded area around every bush or tree is more heavily carpeted with ephemerals than is the open ground nearby In just such spots, too, the seedlings of the large perennials usually make their start

The eastern half of the Sonoran Desert is almost unique among the deserts of the world in having two well-defined rainy seasons, one in mid-summer and one in late winter. In each of these seasons there appears a wholly different group of ephemerals. Never by any chance does a summer species appear in the winter or *vice versa* In the warm moist soil of summer lie the seeds of the winter ephemerals as dormant as if they were in a dry refrigerator This behavior is due solely to a difference in the temperature required for germination of the summer and winter plants. It is an easy matter to secure seedlings of winter ephemerals in summer by appropriate cooling of the soil.

In order to understand the presence of the two sets of ephemerals it is necessary to investigate the geographic distribution of the members of both groups and their seasonal behavior in other regions. There are no species in the winter group which are found only in the area of biseasonal rainfall. All of them are found also in the deserts of California, which have rain only in winter. In fact, the winter ephemerals of Arizona are only a small group of wanderers from the large number found in the Californian deserts. The summer ephemerals, on the other hand, are of southern range, extending into Arizona from Sonora and from the thorn-forest of Sinaloa, where the summer rains are heavier than the winter ones. Here, again, the number of summer species in Arizona is only a fraction of the number found in southern Sonora

Among the winter ephemerals is a small carrot *(Daucus pusillus)*, which ranges from South Carolina to California. In the east it is a summer plant, in the west a winter one. In southern Sonora and in southern Baja California several of the summer plants of the Tucson region have been found growing in the winter rainy period. These cases show that a suitable soil temperature for germination has been a fundamental condition in determining the geographic spread of the ephemerals. In southern Sonora the soil in winter is as warm locally as it is in Arizona in summer, and there is nothing to prevent a summer ephemeral from appearing in both seasons. Such cases are excellent examples of the manner in which organisms spread long distances with little or no modification by following lanes of migration in which they find the conditions to which they are accustomed, even if they be very local or very transitory. In this way the Tucson region has been invaded by a few of the winter ephemerals of California and a somewhat larger number of the summer ones of Sonora. The fact that biseasonal rainfall is a somewhat unusual climatic feature and that it is found over a relatively small area raises a question as to its age in geological terms and the influences exerted on it by minor fluctuations of climate. It seems highly probable that a fuller study of the ephemeral plants, their ranges and relationships, may throw some light on the recent climatic history of the Sonoran Desert.

Succulent Plants

Turning our attention again to the succulent plants we find them to be a richly developed group with a very important place in the vegetation of arid America. The very mention of desert brings to the minds of most travelers a picture of broad landscapes studded with prickly pears, bristling chollas and stately giant cacti. Only a few families have developed succulents in America and the cacti are by far the most important of them, with over 1,200 species. This great group originated somewhere

EXTENSIVE PLAINS

ALONG THE PACIFIC COAST IN BAJA CALIFORNIA ARE DOMINATED BY THE LEAF-SUCCULENT *Agave goldmaniana.*

in tropical America and made its way from the forests through the semi-arid caatinga and thorn-forest into the deserts north and south of its center of origin

The most primitive cactus is *Pereskia*, which has dark stems and rather fleshy leaves It attains the size and form of a small tree, and there is nothing in its general appearance to suggest a close relationship to other cacti The members of the genus are confined to the moist tropics of Mexico and Brazil. In *Pereskiopsis* we have another small genus of cacti, with true leaves but a fleshy green stem and a few weak spines. When the leaves fall from the older parts of the stem its appearance is much like that of some of the slender species of *Opuntia*. From these simple forms have arisen the great array of types now found in the cactus family, the novelty and grotesqueness of which have made them very popular in cultivation in the last ten years.

Several structural features have served to give the cacti their outstanding appearance, so unlike that of other plants Most general have been the loss of the leaf as a permanent organ, the enlargement of the stem to accommodate water-storing tissue, and the development of localized spine-bearing structures known as "areoles" In several genera the stem is segmented into sections, which are flat and somewhat leaf-life; in others the stem is round, much branched and the surface occupied by close-set tubercles In a large group, including massive erect forms as well as slender climbing ones, the stem is grooved or fluted and is thus able readily to accommodate its surface to great fluctuations in the water content of the tissues.

Still further variety is added to the vegetation of the American deserts by several groups of plants in which the leaves are succulent as well as the stems. The largest of the leaf succulents are the century plants, in which the stem is thick and succulent but so greatly shortened that the leaves arise very close together. Similar to the century plants but much smaller are the dudleyas, which are particularly abundant in Baja California

It is very instructive to compare the Sonoran Desert with the Karroo Desert in South Africa with respect to the development of the succulent habit. In the latter there are no cacti, no century plants and no dudleyas, and yet there are plants closely resembling each of them The similar conditions in these two widely separated deserts have brought about very similar types of plants, but they have little family relationship. In the Karroo the place of the cactus in the landscape is taken by members of the Euphorbia family, the place of the century plants is taken by the aloes, and that of the dudleyas by haworthias and gasterias. So far as outward form is concerned we have a case in which unrelated families have made closely similar development in the course of their adjustment to nearly identical climates. We can not yet be sure that these similar but unrelated forms are also alike in their physiological behavior, for the African plants have not been investigated in their native region.

Non-succulent Plants

On turning our attention from the succulent to the non-succulent desert plants we are confronted by a still larger number of species, in which there is even greater variety in those features of structure which are important in the vegetative processes of the plant and in its adjustment to environment There are great differences in the duration of life of the individual plants and of their separate branches In large woody forms the stem may have the normal type of structure found in hardwood trees or may depart from it in almost every feature. The surface of the stem may bear a rough bark or may be

smooth and green, carrying on the principal functions of the leaf.

In the non-succulents the leaf may be perennial, or it may appear only in the warm season, or only in the wet season, or may even require a season which is both wet and warm The size of the leaves is greatly varied, but small ones predominate. In the richly branched palo verde (*Cercidium microphyllum*) there are minute leaves in the rainy seasons, but their total area is much less than that of the green twigs and stems that are doing most of their work. In the beautiful smoke tree of the Salton Basin (*Parosela spinosa*) there are leaves on the very young trees, but they are minute or absent on the old ones, and the crown is made up entirely of richly branched twigs. In the allthorn (*Holacantha emoryi*) there are leaves on the seedling for a few weeks, but the mature tree is green-stemmed and leafless.

Any one who travels through the desert will note that every tree and bush is full of dead twigs and often has large dead branches These represent the backsets to growth which are due to exceptionally dry periods. In effect the twigs and branches are deciduous, much as the leaves are in hardwood trees. An ordinary rainless period of twelve to fifteen weeks will result in the death of all the leaves and branches of a large number of small bushes but only rarely in the destruction of the crowns of their root systems. After the next ensuing rainy season the plants will be as large as ever This is precisely the manner of life of a number of ferns, which seem so much out of place in the desert. Certain species are really true and successful desert plants. Their drought-resistant protoplasm endures the unfavorable seasons without any of the elaborate mechanisms of the larger plants.

Degrees of Success

In our investigations with non-succulent plants we have been led to the view that they not only show different modes of adjustment to desert conditions but have achieved different degrees of success in it. Our criterion of success requires that a plant must have a large area of distribution, must be abundant in some part of its area, must show some degree of elasticity in its habitat requirements and must have solved the problem of withstanding the longest dry periods to which the normal climatic fluctuations subject it Judged by these standards, not more than 20 per cent of the species of non-succulents have achieved a high degree of success

One of the noteworthy plants that shows every evidence of a nice adjustment to arid conditions is the creosote bush (*Larrea tridentata.*) Its behavior and water relations have been investigated at the Desert Laboratory by Dr Mallery and by Dr Runyon They have found that this small-leaved evergreen shrub, which is so abundant from southern Nevada to San Luis Potosi, possesses few of the anatomical characters that are of common occurrence in desert plants and are of such a nature as to aid them in the conservation of water The adjustments of *Larrea* to its arid environment are chiefly functional rather than structural Also it exhibits an unusually high degree of what may be designated "physiological elasticity," by virtue of which its size, rate of growth, density of stand, amount of foliage, size and structure of leaves and size of seed crop vary within wide limits, according to habitat and season

Physiological Behavior

It is necessary, therefore, in making an estimate of the diversity of desert plants to consider not only their conspicuous differences in form and structure but also to know something of their physiological behavior. Since this requires prolonged investigation of each species it is natural that our knowledge

of their functional features lags far behind our knowledge of their morphology

The reduction of green surface which is universal in the cacti of the Sonoran Desert and very common in the non-succulents serves to decrease greatly the amount of food manufacturing that such plants are able to do We still know little about the character of the photosynthetic process in green-stemmed leafless desert plants as compared with broad-leaved plants. Also we know little about the effect of low water supply and brilliant illumination on this important process The development in cacti of the heavy surface which protects their moist tissues and the almost continuously closed position of their stomata are serious impediments to the free exchange of gases, which is so important in both photosynthesis and respiration. Enough work has been done on the physiology of some of the massive cacti to show that their respiratory behavior has many features of difference from that of non-succulent plants.

In recent work our interest has been attracted to several trees and shrubs which are abundant in the desert plains of Sonora and, like *Larrea,* have few obvious features of the sort that we are accustomed to regard as characteristic of desert plants. It is certain that an understanding of the place of these shrubs in nature must await investigation of their physiology, their life-histories under natural conditions and their probable origin and distributional movements.

Mesquite and Tésota

Prominent among these shrubs are members of the large family Leguminosae, which has contributed several highly modified species to the desert flora and is abundantly represented in the arid and semi-arid regions of all the continents. The most widely distributed leguminous trees in the North American deserts are the species of mesquite (*Prosopis*). In general appearance the mature plant resembles a peach or apple tree. The leaves are compound and the leaflets very small. It is only in the most favorable situations that the mesquite is found as a tree. In less favorable ones it is merely a shrub. Its roots often extend to a depth of 40 feet in the alluvial clay of flood-plains.

Work on the physiology of the roots as well as on the moisture conditions in deep soil has helped to elucidate the abundance and rapid growth of this tree. It is winter-deciduous and its new foliage appears in the spring at the very time that the winter ephemerals are dying from drought, and every week is hotter and drier than the last. The roots are able to function at the cool temperature of the lower soil levels and at that depth can secure water from a supply which is nearly constant throughout the year. Thus are the mesquites of the flood-plains able to expose their great extent of leaf surface without danger of insufficient water supply.

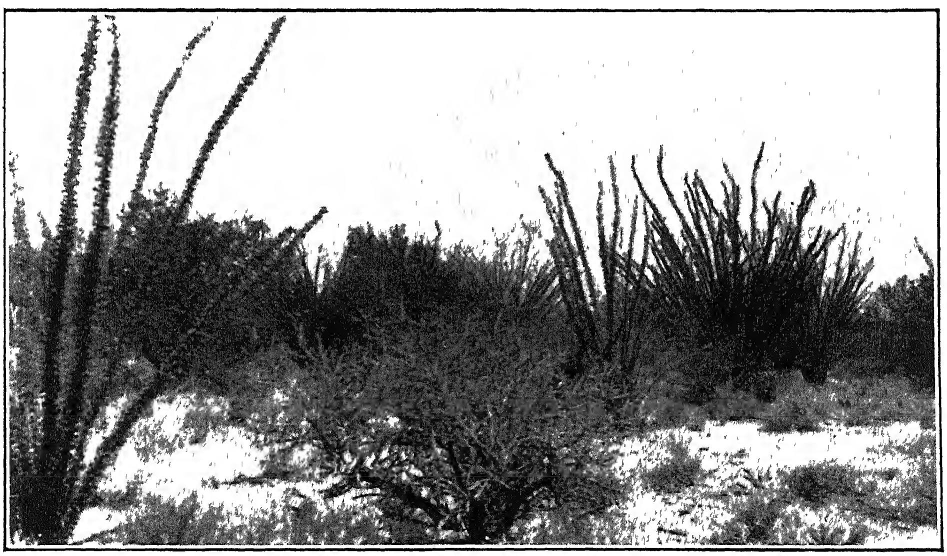
On the desert plains, where the mesquites are uncommon and small, the soil is shallow or filled with calcareous hardpan, and there is no deep-seated accumulation of water. Work has been done on the daily course of water loss from small mesquite trees in dry situations in dry months. Atmospheric evaporation rises rapidly from sunrise to a maximum at 1 or 2 o'clock in the afternoon. The loss of water by the mesquite also begins to rise rapidly at sunrise and its hourly increase continues until 9 or 10 A.M. Then comes a sudden break in the rate of loss, which falls to its early morning amount and remains there until 4 or 5 P.M The tree does not prodigally throw off more water than it is able to get out of the soil and to transmit to its leaves at times when the evaporation is very high

Considerable work has been done at the Desert Laboratory on the mecha-

nisms which enable a plant to control its loss of water The closing of stomata, rising osmotic value of sap and changes in the manner in which the water is held, or "bound," are all of importance. Also there is evidence that a high rate of loss breaks the continuity of the minute columns of water that are moving toward the leaves. This is probably the principal cause of the mid-morning check in the rate of water loss by the mesquite. The night is important in bringing conditions that enable plants to restore the continuity of their water movement and the moisture content of their tissues. As Livingston once said, "If the celestial machinery should break down so that just one night was omitted in the midst of a dry season it would spell the doom of half the non-succulent plants in the desert."

Another leguminous tree, the tésota (*Olneya*), has gone further than the mesquite in emancipating itself from favorable localities and in surviving in the driest parts of the Sonoran Desert In every visible feature that might concern the water relations tésota closely resembles mesquite. Further investigation is needed to uncover their differences Tésota is the only member of the genus *Olneya*. Its geographical range is nearly coincident with that of the Sonoran Desert Its nearest relatives are certain trees and shrubs (*Eysenhardtia, Willardia*) found in and near the southern part of the Sonoran Desert, all of them with a water requirement higher than in tésota. The manner in which mesquite is pushing out from the favorable flood-plains on to the unfavorable desert and developing water-conserving habits suggests the possible history of the tésota It is now far from its nearest relatives in the characters on which its classification depends and also in those that determine the sort of region and habitat in which it grows.

As is well illustrated in the case of mesquite and tésota, the behavior of a desert plant and its place in nature can be learned only through the conjunction of detailed laboratory work and widely extended observation in the field. The



HEAVY TYPE OF VEGETATION

FOUND ON GRANITIC SOIL IN THE PLAINS OF WESTERN SONORA. CONSPICUOUS PLANTS ARE *Fouquieria splendens, Olneya tésota, Opuntia thurberi* AND *Franseria deltoidea.*

Desert Laboratory offers almost ideal opportunities for the employment of intensive and extensive methods in the pursuit of its problems

The Sonoran Desert

The boundary of the Sonoran Desert is sharp in certain places where the topography is rugged and the climatic change abrupt. Its northwestern and southern limits are indefinite, for in the former it merges gradually into the Mojave Desert, and in the latter passes by easy stages into thorn-forest Most of the thorn-forest region, which stretches south for 1,500 miles along the west coast of Mexico, is semi-arid, but it merges along its eastern edge into humid mountain forests and jungles. It is the link between desert and tropics in western North America.

It is well known that the climatic fluctuations of recent geological time brought about profound changes in the plant life of northern North America. The advance and retreat of the extensive ice sheets was accompanied by movements of plant species and of types of vegetation which were alternately pushed south or given an opportunity to move north. The immediate effect of the presence or retreat of the ice sheets was local, but the fluctuations of climate which controlled the ice were far-reaching. There is physiographic evidence in the Sonoran Desert that there have been fluctuations in its rainfall in recent geological time, and it is presumed that there were accompanying fluctuations in temperature.

Very little is known about the amplitude of the pulsations, and their chronology can only be presumed to have a close relation to that which has been tentatively worked out in the north. So closely are the limits of the desert determined by climatic conditions to-day that we can see how surely every change of climate was followed by the movement of plants On the southern edge of the Sonoran Desert the pulsations have been particularly important, for the thorn-forest has a large flora and every wetter or warmer period has permitted some of its species to travel north

Migration Paths

If we examine a map of the Sonoran Desert we will note that there are long stretches of country lying in a nearly north and south position which are not broken by large bodies of water or lofty transverse mountain ranges These stretches have afforded paths along which it has been possible for plants to move north or south as the climatic conditions have slowly changed. From the northern edge of the Mojave Desert southward along the coastal plains of Sonora for 1,000 miles is a path through open country at low elevations, which we designate the Coastal Path

A second runs parallel to the first through Baja California, traversing country more rugged but also low in elevation—the Peninsular Path. A third runs through the foothills of Sonora and Arizona at altitudes of 2,000 to 4,000 feet—the Foothill Path. A fourth lies in the higher mountains of the Sierra Madre and ends in the scattered ranges of southeastern Arizona—the Mountain Path. Far to the east in the Chihuahuan Desert doubtless lie other paths which have not yet been investigated or defined.

The two paths which border the Gulf of California are of particular interest, because they lie at the same low elevation and are closely parallel in their climatic character The Foothill Path runs through country which is somewhat cooler and less arid than the coasts of the Gulf. The Mountain Path is wholly outside the desert but has some important relations to the Foothill Path. Whatever general changes of climate may have affected the Sonoran Desert region in recent geological time, the

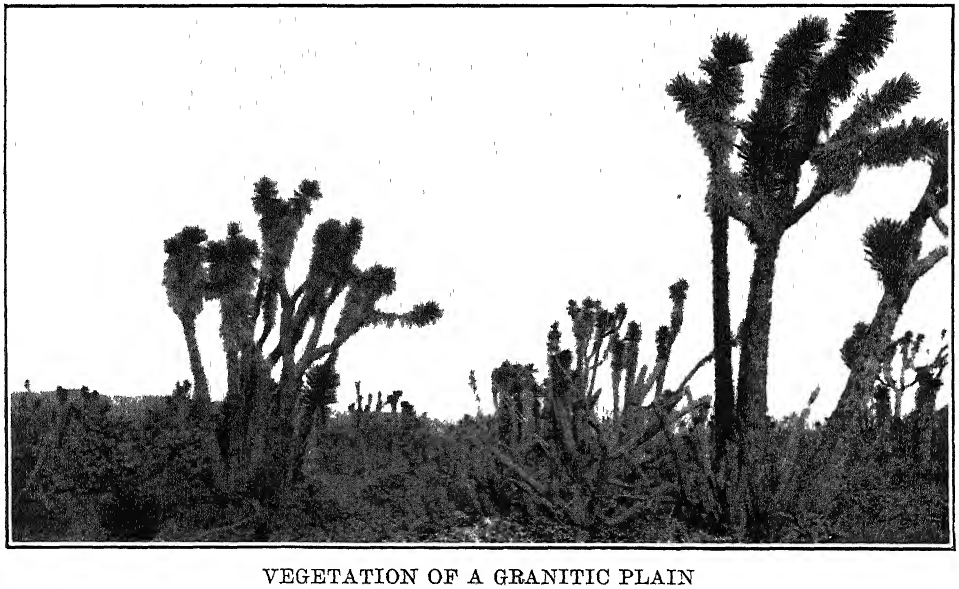
three mainland paths have continuously differed from each other in climate as much as they do to-day.

Evidence that the four paths have served for extended movements of plants is based on the study of the distribution of the common species of the area. The majority of them range north and south for much greater distances than they do east and west. Plants in the Peninsular and Coastal Paths have had a physical barrier in the Gulf of California, which has made interchange between them difficult. Plants in the three mainland paths have had climatic barriers which served to lessen the ready movement of plants out of one path into another. In each path it has been easier for plants to advance or retreat for a long distance north or south than to move a short distance east or west into the adjacent path. Thus have come about the long narrow distributional areas that characterize so many species.

In order to understand events in the Sonoran Desert it is necessary to know something about the regions adjacent to it. Some of its plants are merely the remote pioneers of groups that have their principal development far to the north or south. There are many cases in which a genus of plants is represented by several species at the southern end of one of the paths but loses them one by one as the path stretches northward, until only one species crosses the International Boundary. The same thing is true of the southward movement of numerous genera that have their present centers of development in the Mojave Desert or the Great Basin.

Agencies in Evolutionary Development

It must be remembered that the plant migrations we are considering took place very slowly over periods of thousands of years. In some cases the very same species advanced, retreated and advanced again with little or no change in its identity. There is abundant evidence, however, that climatic variations, changes of surface and soil and enforced movements have been important agencies in



VEGETATION OF A GRANITIC PLAIN

NEAR PUNTA PRIETA, BAJA CALIFORNIA, WITH THE GIANT CACTUS *Pachycereus pringlei*, *Idria columnaris*, THE FAT-STEMMED TREE *Pachycormus discolor* AND *Agave nelsoni.*

LANDSCAPE DOMINATED BY *YUCCA VALIDA*

ON THE INNER EDGE OF THE VISCAIÑO DESERT, IN BAJA CALIFORNIA. THE CACTI *Machaerocereus gummosus* AND *Opuntia calmalliana* ARE ABUNDANT.

shaping the evolutionary development of plants. The genera and species which are found only in the Sonoran Desert are the product of these agencies. In several of the groups endemic to the area there are series of related species, occupying areas which overlap very little and lie in a chain along one of the paths of movement Such unbroken chains, which combine evidence of migratory movement linked with evolutionary activity, appear to be relatively recent in their formation. If they were old there would be more distant relationship between the links, the chain would be broken, and some of the links would be gone.

One of the cases in which the evolutionary history of a genus is illuminated by the geographic distribution of its species is the group of barrel cacti of the genus *Ferocactus* There are thirty-two species of these, twenty-four of which are either local or very poorly known The other eight are of wide distribution and play an important part in the vegetation of their respective areas. In the cactus genus *Opuntia* similar chains extend from the south, with slender links in Sinaloa and southern Sonora, and end in the Gila or Colorado valleys with a strong cluster of forms. The inference is strong that in such groups as *Ferocactus* and *Opuntia* there has been steady movement accompanied by the appearance of new species and that these phenomena have taken place in very recent time in the geological sense.

It is natural that we have more evidence of recent events than of older ones, as the later movements have done much to obscure the earlier In a few cases, however, single widely separated links have been found which are recognized as belonging to the same chain, broken and scattered long ago There are genera in which the species do not show a close relationship and are now distributed irregularly around the end of one of the paths of migration. There are species which exhibit a scattered and discontinuous distribution, which is uncommon among the dominant plants of the area.

It is obvious that these are cases in which the genus or the species has lost some of the ground which it formerly occupied The genus is no longer distributed in such a way as to give a hint of the sequential relation of its members. The species is no longer distributed so as to accord with the majority of plants that now range along the lanes of migration, nor does it occupy all the area in which the conditions are favorable for it The evidence suggests that these plants belong to an older wave of movement. Indeed, it is possible that some of them have endured all the climatic pulsations of the Pleistocene and Recent periods and have either made repeated movements or else have stood their ground and developed the ability to live under a wider amplitude of physical conditions than some of their associates have.

The historical problems raised in our work on the Sonoran Desert are very fascinating, in spite of the difficulty in securing full and conclusive solutions to them In the recent history little help is to be anticipated from fossil records Desert conditions are not favorable for the preservation of plant remains, and those that are found in old lake beds or alluvium are apt to be misleading An interest in the historical background of our problems does much to enlighten the more concrete and equally important work of studying the relation of the present vegetation to the soils, climate and other physical agencies of to-day.

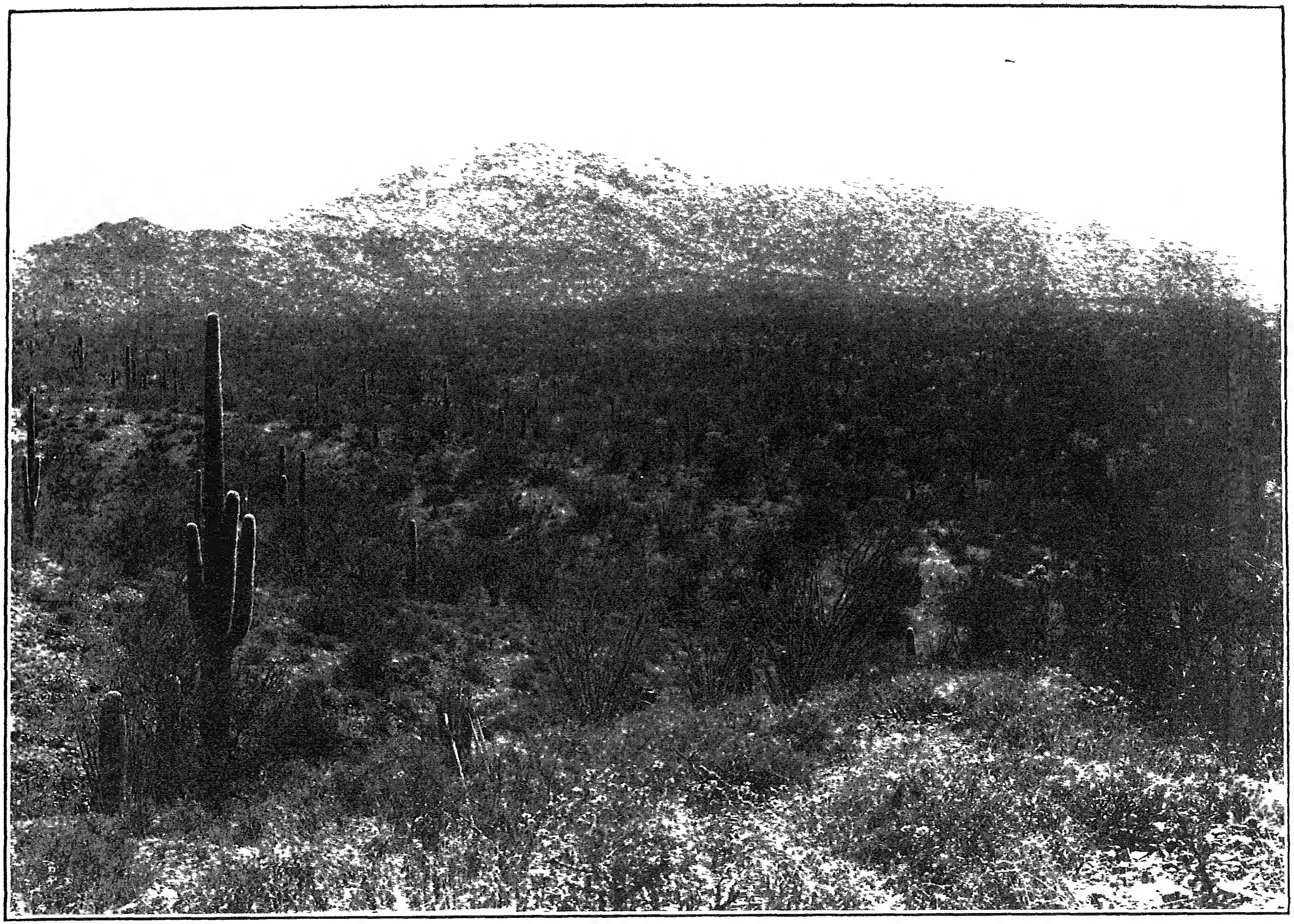
Sonoran Climate

The Sonoran Desert stretches from Lat 24° N. to Lat 35° N, lying at the southern edge of the temperate zone This means that its area embraces differences in winter temperature which are important to plants. Along the northern edge there are from twelve to sixteen weeks of the winter season in which frost is apt to occur and in which the minimum temperature may fall for a few hours as low as 16 to 20° F. At the southern edge frosts are light and infrequent. Summer temperatures are high throughout the area

The distribution of mountains and large bodies of water is such that differences of latitude affect the duration of the hottest season but do not have a consistent influence on the highest temperatures that are reached The influence of high temperatures on the distribution and physiological performance of plants is registered in intimate connection with the influences of restricted soil moisture and high rates of transpiration. The influence of low temperatures is much less intimately connected with the water relations, at least in non-succulent plants.

Our work indicates that the poverty of the flora in the driest parts of the Sonoran Desert is due as much to the joint influence of aridity and the low temperatures of winter as it is to the aridity alone. The warmer southern edge of the desert has many species of perennial plants which are highly drought-resistant but are not able to push north into the region of heavy frost. Detailed investigation of the relation of topography to the distribution of low temperatures has enabled us to appreciate the fact that these plants have their northernmost occurrence in the warmest spots. Whether any of them are capable of ranging still further north requires the test of experimental cultures, the results of which may indicate that certain species have not yet reached the northernmost limit at which they can grow.

The differences in rainfall which are found in the Sonoran Desert are wholly independent of latitude and are controlled by the larger air movements, modified by the influences exerted through differences of altitude and through the distribution of large mountain ranges. The most arid part of the desert lies on the eastern or lee side of the great mountain ranges of northern Baja California and southern California Almost equally arid are the Pacific and Gulf



THE HEAVIEST VEGETATION OF A TRULY DESERT TYPE

IN THE NORTHERN HALF OF THE SONORAN DESERT IS FOUND ON OUTWASH PLAINS NEAR LARGE MOUNTAINS AT ELEVATIONS BETWEEN 2,000 AND 3,000 FEET.

coasts of Baja California and the Gulf coast of Sonora. Along the Pacific coast the atmospheric humidity ranges higher than in the interior, and at certain seasons there is morning fog for ten or fifteen miles inland. These conditions favor the growth of lichens and the air plant *Tillandsia,* but they do little to ameliorate, for larger plants, the effects of dry soil and incessant wind.

It means little to say that nearly half of the Sonoran Desert has a mean annual rainfall of less than five inches. It is the irregularity of the rain storms and the long periods of drought which are of importance. In Baja California the town of Santa Rosalia, after four years with no rain, was visited by a downpour of three inches in two hours in August, 1933. Even after several rainless years leaves will be found in the spring on *Idria,* flowers on *Pachycereus* and leaves and flowers on *Viscainoa.* After one of the heavy downpours there is a prompt response on the part of all classes of plants. About once in every eight to fifteen years the driest sections of the desert are visited by successive rains. Only at such times is it possible to determine the full extent of the flora, the complete make-up of the vegetation and the optimum growth and development of the plants.

The inner edge of the Sonoran Desert, from the Gila River to the southern boundary, has an average annual precipitation ranging from eight to fifteen inches. In this territory there are two rainy seasons and the periods of drought are therefore much shorter than they are on the Pacific coast or along the western edge of the desert.

Sonoran Vegetation

The differences of climate which may be found in the various parts of the Sonoran Desert, together with the varied character of its topography and sharp differences in the nature of its soils, all serve to give the vegetation greater variety than might be expected in a region which presents so many obstacles to the best development of plants. The limited number of species of woody perennials to be found in the driest sections serves to make the presence or absence of a single species more important in the physiognomy of the vegetation and the appearance of the landscape than would be the case if a rich flora existed there.

A comparison of the communities reveals almost every gradation in the features which characterize desert vegetation. The prevailing stature of the dominant plants is low, but varies from pure stands of *Atriplex* or *Franseria* less than 10 inches high to open forests of *Olneya* or *Cercidium* fifteen to twenty-five feet in height. The spacing of the individuals is characteristically wide, but it varies from stands in which there are many bare places with a diameter of forty feet to others in which the branches of the shrubs almost meet.

An intermingling of diverse types of plants is another typical feature in which there is variation from local colonies of a single species to extensive areas of great variety. Still further differentiation is given the most widely separated parts of the Sonoran Desert by the distributional limitation of its common and characteristic plants. In fact there are very few perennials of importance in the make-up of the vegetation which are found throughout the area.

The plains and mountains which border the lower course of the Colorado River and the head of the Gulf of California have the smallest flora and the most scanty vegetation of any part of the North American Desert. One may walk across the outwash plains of Yuma County, Arizona, for a long distance without being able to count more than sixteen species of perennials, and the vegetation is so open that it is possible to walk a straight course with few deviations. The most abundant plants are the creosote bush (*Larrea tridentata*)

and the chamiso (*Franseria dumosa*). Along the streamways are occasional large individuals of tésota, smoke tree or ocotillo. On the hills and mountain slopes there are a few widely separated shrubs and cacti, but at a short distance most of the mountain ranges appear to be wholly devoid of plants.

In Baja California

In central Baja California the rugged volcanic surface bears an open stand of small shrubs together with scattered individuals of the unique cirio (*Idria columnaris*), the cardon cactus (*Pachycereus pringlei*) and large century plants. In broad plains with deeper soil are to be found fine examples of some of the plants which are confined to Baja California, including cirio, with its heavy erect trunk bristling with short branches, and the torote (*Pachycormus discolor*), a beautiful little tree with smooth cream-colored stems, the size of which is out of all proportion to the height of the tree.

Two hundred miles farther south the cirio has been left behind and the landscape is dominated by a tall yucca (*Yucca valida*), several abundant cacti, and another ocotillo (*Fouquieria peninsularis*), with poorly branched widely divergent arms. The southernmost areas of desert in Baja California still have all the earmarks of arid country, but there is a pronounced thickening of the stand, an increase in the number of tall individuals, an even greater display of plant types and a much richer perennial flora. Here are slender erect types of cacti well suited to live in the scrub, numerous drought-deciduous shrubs and occasional flat-topped acacia trees, the dominant plants of the thorn-forest area which occupies part of the cape district of the peninsula and stretches far to the south on the mainland.

In the foothills of the mountains of southern Baja California and in the narrow valleys which traverse the arid volcanic mesas is to be found an almost luxuriant vegetation with a blending of the ecological features of desert and tropics, a mixture of their respective plant types and a mingling of their floras.

Near the head of the Gulf of California its eastern and western coasts are very similar in their vegetation. On traveling eastward from that region on to the higher outwash plains around Phoenix and Tucson there is a conspicuous change in the vegetation. There are more plants per acre, more large individuals and more kinds of plants. It is in this region that the cacti are most abundant and diversified, broad plains are more completely covered by the creosote bush, and coarser slopes bear open miniature forests of palo verde and tésota.

South of International Boundary

South of the International Boundary is a vast plain which rises gradually from the Gulf of California, is studded with hills and small mountains and narrows gradually toward the south. The vegetation of this region, which comprises nearly half of the state of Sonora, differs in many respects from that found at the same latitudes in Baja California. Over extensive areas the tésota and the low gray shrub incienso (*Encelia farinosa*) are the dominant plants, with the creosote bush restricted in its occurrences and the cactus display much less impressive than it is in Arizona. Three species of palo verde and the mesquite are abundant on the most favorable soils, in the bottomlands of the broad valleys, while on the least favorable ones there is a low and open stand of salt bushes or chamiso.

Between 100 and 200 miles south of the International Boundary the hilly country which forms the inner edge of the Sonoran Desert is strikingly different from the plains of the coastal region. Slightly greater rainfall and slightly

milder winter temperatures do much to improve the conditions for plants, but the climate is still distinctly an arid one. It is here that many trees and shrubs are found which are drought resistant but not frost resistant. They mingle with the plants which range further north and the two groups occupy the same terrain without severe competition and with resulting increase in the density of the vegetation.

In Southern Sonora

As the coastal plain grows narrower in southern Sonora and the mountain background lies nearer the coast, there is a marked change in the vegetation of both hills and plains. The general features of this change are like those found in Baja California, but it is more gradual in Sonora and takes place somewhat farther north. South of the Yaqui River there is much of the desert in which it is not possible to walk a straight course for more than a few yards, or to go very far without the use of a machete. The stature of the trees has increased very little, but their number per acre is much greater. Smaller plants are no longer clustered more densely in the shade of the trees but grow everywhere. Streamways are no longer discernible at a distance by their fringe of heavier vegetation but only by their slightly taller trees and their dense thickets of shrubs and vines. The cacti of the open desert begin to give way to species which endure the shade of the thin tree-tops. The soil reacts to the heavier vegetation and contains much more organic matter. The runoff is more gentle and the larger streamways have pebbly bottoms and rounded banks which form a sharp contrast to the sandy bottoms and steep bare banks of the streamways which carry only the violent flash floods of the more arid parts of the desert.

From the conditions in the Yaqui Valley it is only a short step to those in the valleys of the Mayo and Fuerte, where the characteristics of the thorn-forest prevail over those of the desert. This is one of the most interesting of the many places in which it is possible to study the gradual changes which lead from the desert to other types of plant life.

Biological Work in the Desert

The value of biological work in the desert resides largely in the fact that organisms may there be studied under extreme conditions. The physiological behavior of the individual and the evolutionary development of the race may both be investigated as they manifest themselves in an adverse environment. Even within the desert, however, there are localities and habitats which are more extreme and others which are less so. In our work we have found it instructive to study the entire range of conditions, for in the heart of the desert we find the few plants which are most closely adjusted to great aridity, and along the edge we find forms only imperfectly suited to it, from which there will doubtless develop in time new species capable of penetrating to the center of the desert.

The most important aim of our work is to keep in view the vast array of influences and circumstances that have determined the history of desert plants and now determine the life and survival of every one of them. We need the results of highly specialized work, but we need even more to interpret these results through an intimate knowledge of the plants on their dusty alkaline plains or sun-baked volcanic hills. Especially do we need to weave together the separate threads of knowledge about the plants and their natural setting into a close fabric of understanding on which it will be possible to see the whole pattern and design of desert life.

SCIENTIFIC METHOD IN THE INVESTIGATION OF ECONOMIC PROBLEMS[1]

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ALTHOUGH the so-called science of economics is as old as the American Republic, discussions still persist as to whether the subject can in any true sense be regarded as scientific in character. Indeed, as a result of the economic disorganization of the present day and the confusion of counsel which exists, the question is raised more often now than in former times.

I begin by saying that there is no such thing as *the* scientific method. There are as many different scientific methods as there are different fields of knowledge; in fact, various types of methods may be used within any given field or even in a single investigation. Being scientific is a matter of *spirit* and not of *method*. This spirit is not the exclusive possession of the scholars in any particular realm of inquiry.

It is not my purpose to assert that all economists are imbued with a truly scientific spirit; on the contrary, I believe that the percentage of workers in the field of economics who are unscientific, at least in certain respects, is much greater than that in the natural sciences. We doubtless have more than our share of charlatans, special pleaders, reformers and incompetents—for it is, unfortunately, even easier for the economic quack to gain a hearing than it is for the astrologer and the phrenologist.

If a better understanding is to be developed between natural scientists and economists, it is essential that I speak plainly with reference to a prevailing tendency. Mathematicians, physicists and engineers often assume that economists have never had a course in mathematics, logic or physics, and that the scientific method is a sealed mystery to us. When, however, they turn to writing on economic subjects they frequently display a lack of scientific attitude which is to us truly appalling.

Other natural scientists and mathematicians, while not presuming to speak authoritatively on economics, are nevertheless convinced that what economics really needs is a few first-class men thoroughly trained in mathematics or some other field of the natural sciences.

For example, a distinguished engineer, in a recent volume, starts out by implying that economics has heretofore been wholly unscientific in character and that we must look to engineers trained in the precise methodology of mathematics and engineering to find a solution of our economic difficulties. He states in his introduction: "When we come right down to it, the engineer designed the mechanism of the [economic] system even if he had nothing to do with the design and application of the control devices. Therefore he ought to be able to say why it does not function in a proper manner." It is incredible to me that one trained in precise thinking should be unable to see the *non-sequitur* in this statement. The fact that engineers build bridges or industrial plant and equipment of course provides no basis whatever for an understanding of the "control devices" with which economics is primarily concerned.

This author then goes on to state that "no one seems to have approached the problem from the production end instead

[1] Address at the St. Louis meeting of the American Association for the Advancement of Science, January 2, 1936.

of from the consumption terminus." Now even a slight acquaintanceship with economic literature would have revealed that the whole classical system of economic analysis approaches the problem from the production end; indeed, it is only in comparatively recent times that a correction has been attempted by attaching more importance to consumption in relation to production.

It is not open to dispute that the training in close, precise thinking that mathematics affords is of the greatest importance. It is also true that mathematics is a useful tool for economics. The application of mathematical methods has rendered much service in connection with the study of statistical averages and probabilities, and in measuring the degree of consilience between correlated statistical data. But it does not follow from this that a mathematician can carry over his general methodology into economics and obtain fruitful results any more than he can carry it into biology or medicine and discover new truths.

It is not commonly realized that a considerable number of men possessed of a thorough training in science and mathematics have undertaken to apply their methodology in the field of economics —from Simon Newcomb to Frederick Soddy. In the main, these men have tended to over-simplify the problems involved, to make naive abstractions and unreal assumptions and thus to obscure rather than reveal the truth. Their lack of familiarity with actual economic processes and relationships proves their undoing.

There are of course exceptions to the generalization that natural scientists have not made great contributions in economics. The chief of these is Alfred Marshall, who published his great volume entitled "Principles of Economics" in 1890. Marshall's was admitted to be one of the really great minds of the second half of the nineteenth century. His early training was in the field of mathematics and psychology, and he had reached mature years before he began the systematic study of economics. While he made considerable use of mathematical tools, he came to see clearly that the mathematical method was of limited applicability in the discovery of economic truth. He pointed out that the more a complex problem is broken up for purposes of study with a view to segregating disturbing influences by the assumption *other things being equal,* the less closely do the results correspond to real life. He wrote:

> I had a growing feeling in the later years of my work that a good mathematical theorem dealing with economic hypotheses was very unlikely to be good economics: and I went more and more on the following rules: (1) Use mathematics as a shorthand language, rather than as an engine of inquiry. (2) Keep to them [these mathematical symbols] till you have done. (3) Translate into English. (4) Then illustrate by examples that are important in real life. (5) Burn the mathematics. (6) If you can't succeed in (4) [that is, in illustrating by examples that are important in real life], burn (3) [that is, the English statement of the principles deduced]. This last I did often.

Even though the first assumptions may be realistic, the conclusions derived by the process of isolating disturbing variables may be quite invalid as explanations of the actual world. This is why Marshall advises against mathematics as a method of inquiry.

Let me say again in conclusion that I do not wish to be interpreted as holding that mathematics has not been a useful tool in connection with economic analysis and that it may not be made more useful in the future. While I should be distrustful of completely independent work on the part of a mathematician in the field of economics, I should, on the other hand, be quite hopeful of important results being achieved through close collaboration between mathematically trained workers and economists inti-

mately acquainted with the processes of the complex economic system.

ECONOMICS IN A CHANGING WORLD

My primary object on this occasion, however, is not to discuss the applicability of mathematical methods to economic analysis, but to point out why we must expect a larger measure of disagreement among economists than is likely to be found in any division of the natural sciences and why, in the nature of the case, we can not expect to formulate a complete set of economic principles of universal and eternal applicability. At the conclusion of this discussion I shall present for your consideration the methodology employed in a recent investigation in economics with which I have been associated in order that you may see the character of the methods which have been employed.

As a point of departure I must point out that early writers in the field of the social sciences were directly under the spell of the scientific spirit and the scientific outlook which had already developed in the fields of astronomy, mathematics and physics. It will be recalled that it was in the sixteenth and seventeenth centuries that such men as Galileo, Kepler and Newton discovered and formulated some of the basic laws which govern the physical world. In the course of the ensuing century these scientific discoveries came to exert a profound influence upon men's ideas in other realms of thought. It came to be asked whether man himself was not as much a part of and controlled by an orderly universe as the physical earth on which he lived.

The great problem appeared to be to discover the laws which govern human action and, through human action, social and economic progress. Early writers, such as Blackstone, Rousseau, Godwin and Adam Smith, found the answer in a system of *natural law* which, if not interfered with by governments or other human institutions, would always lead to progress.

During the century ending in 1850 a body of economic principles was gradually evolved. An elaborate system of economic conclusions was developed on the basis of a comparatively few simple laws which were rooted in physical factors. Among these may be mentioned, for purposes of illustration, the following general principles: (1) the law of diminishing returns, which holds that beyond a certain point the application of additional labor and capital to a given amount of natural resources does not yield a proportional increase of product; (2) the law of diminishing utility, which holds that beyond a certain point the satisfaction derived from the consumption of additional units of any given commodity declines; and (3) the law of the variability of human desires, which holds that human wants as a whole are virtually insatiable.

The extension of economic activity throughout the world, the development of infinitely varied types of product and the whole complex system of production and distribution, involving varying and constantly changing commodity values, are the direct results of these fundamental attributes of nature and of man. These underlying principles or laws, and also a great number of secondary principles derived therefrom or articulated therewith, have long been the subject of universal agreement among economists.

It is true, however, that there are many differences of view among reputable economists with reference to issues of primary significance, and it is true that the extent of agreement is vastly less at this particular juncture in the development of economic thought than was formerly the case. After John Stuart Mill published his great treatise in 1848 it was believed, in the Anglo-Saxon world, that almost the last word on political economy had been written—that Mill's analysis had rounded out a body of economic principles that would remain forever as an adequate explana-

tion of the operation of economic forces. In 1850 economics was as settled and complete as the science of physics was considered to be in 1890.

In the ensuing forty years, however, a group of continental economists, chiefly Austrian, approached the problem from a somewhat different angle, giving much more weight to psychological factors affecting human conduct and hence the laws of value and distribution. In 1890, as already indicated, Alfred Marshall brought out his principles of economics which integrated the analyses of the Austrians with those of the English classical school and showed how the two might be harmonized.

To-day, as a result of changes to which I shall presently refer, a considerable part of the formerly accepted body of economic doctrine is subject to challenge, and some of it has been definitely dethroned. One reason is that the accumulation of a vast body of recorded data bearing upon economic issues has made it possible to test the validity of many of the assumptions on which the classical analyses were based. However, a more fundamentally important factor has been the changing character of the economic system itself.

And here I come to a statement of what I conceive to be the basic difference between economics and the natural sciences. While the underlying principles of economics are based upon natural forces, the economic system by means of which productive activities are carried out is constantly undergoing evolutionary change. The natural sciences, on the other hand, are concerned with the observation of physical forces which are practically permanent in character. The complex economic machine which has resulted from certain natural laws and the growth of human institutions has undergone a rapid evolution even in the course of our own life span. Time is not available in which to cite concrete illustrations of the way in which the economic machine has changed in character. It must suffice for the present purpose to point out that *as* it changes economic thought must perforce be modified to take account of the working of the system under new conditions. A phrase —*the relativity of economic thought*— has been developed to indicate the necessity of an evolutionary body of economic thought paralleling evolutionary changes in the economic system. In a dynamic world we must perforce have a pragmatic economics.

In view of the constantly changing character of the economic system, it is not surprising that there should be at a time such as the present wide differences of opinion among economists. In the nature of the case we do not all have the same body of factual data at our command; and our interpretations of the way in which the economic machine operates at any given time will in consequence vary. The degree of disagreement is, moreover, increased as a result of the fact that some economists are constantly endeavoring through the study of quantitative data to discover new light, while others prefer to hold fast to the accepted body of doctrine.

The history of human thought in all lines reveals a type of person who is reluctant to relinquish old concepts and conclusions in favor of new ones. It is found, I am told, even in physics and mathematics. Although the necessity of a flexible and evolutionary thought is particularly necessary in economics—in view of the changing character of the economic system—the tendency to adhere steadfastly to the principles laid down by our predecessors is, I believe, particularly marked. I am sometimes reminded of the mother who warned her son when he went to college not to let these university teachings unsettle his religious beliefs. Upon returning from college the young man confessed that some of the things which he had learned necessitated a modification of the relig-

ious views which he had formerly held. After giving the matter consideration for a moment the mother said: "Well, my son, we will hope that it isn't true; but if we find that it is we will keep still about it."

The evolutionary character of the economic system, necessitating an accompanying evolution of economic thought, produces quite different reactions in the minds of different scholars. To the individual in quest of the ultimate, as many economists have been, it is discouraging, even demoralizing, to discover that changing conditions necessitate the abandonment or modification of cherished beliefs. To the individual who finds his greatest satisfaction in the perpetual discovery of new truths, however impermanent in character they may prove to be, the fact that the economic world constantly undergoes change only heightens the intellectual satisfaction derived from the study of economics. The vein can not be worked out; the quest for knowledge and understanding is never ending.

Now if it be true that the economic world, which is the subject of the economists' study, is undergoing constant change, does it not follow that economics can never hope to be an *exact science?* The answer is clearly yes, if one means by exact absolutely precise and permanently unchanging. But it is not true that at any given period of time it is impossible to prove anything, that it is all guesswork, that one man's conclusion is as good as another's.

There is a considerable body of principles that remain always true—though they are sometimes overlooked or forgotten, even in the halls of Parliament. Moreover, it is becoming increasingly possible to subject debatable issues to statistical verification—though as yet the data often lack the precision we should like. Owing to the great progress which is being made in the systematic recording of factual information—which constitutes our primary laboratory material—I foresee in the next generation a substantial narrowing of the area of disagreement as to the working of economic forces. But economics will still not be as *exact* as mathematics.

Economic Methodology Concretely Illustrated

I shall now turn from these general considerations to a specific economic investigation, for the purpose of indicating the character of the methodology involved. As I have already indicated, varying economic problems require somewhat different methods of analysis; indeed, a single problem may involve a combination of methods. The investigation which I shall use for purposes of illustration is that recently concluded by the Brookings Institution under the general title, "The Distribution of Wealth and Income in Relation to Economic Progress." Because of the repercussions of a retarded rate of economic growth upon the practical application to productive processes of the results of scientific investigations in the field of the natural sciences, I trust you may be interested in the analysis itself as well as in the question of methodology.

The very wording of the title—the distribution of income in relation to economic progress—which was chosen before the investigation was begun—suggests that we had some sort of an hypothesis which we were interested in testing. The apparent fact that business enterprises seldom produce at full capacity, and that the greatest problem of business managers appears to be to find adequate markets for their products, had raised in the minds of many business men and economists the question, "Does not a lack of purchasing power among the masses perhaps serve to prevent the full employment of our productive resources?" And this thought led at

once to the correlative question, "What is the possible bearing of the distribution of income among the different groups in society upon the demand for the products of industry?"

Views both as to the facts about production and as to the possible effects of an unequal division of income upon the functioning of the economic system were widely at variance. It was our belief that a searching study into the interrelations between production and consumption as revealed by data and information drawn from the actual world of affairs might yield results of basic significance. I must make it clear at this place that we were not directly concerned with ascertaining the causes of depression. Our interest was in discovering whether, even in periods of prosperity, there might be in operation factors or forces which impeded the full utilization of our economic resources.

In order to reveal the character of the investigation required and the methods employed, I shall describe very briefly the several steps that were involved in the analysis.

Step 1. The first step was to ascertain the degree to which our productive resources are, in fact, utilized. If investigation should show that in a period of prosperity such as that of the late twenties they were employed at full practical capacity, then it would be unnecessary to carry the investigation further. We surveyed statistical and other data bearing upon the productive output of the different divisions of our economic system, including mining, manufacturing, etc. We made allowances for numerous practical problems confronting the various industries which might as a practical matter reduce actual capacity below theoretical possibilities. In the more difficult cases, we checked our findings with representatives of the industries concerned, with a view to making sure that we had not overlooked any practical considerations. We found, in brief, that in the prosperity period of the twenties our productive facilities were used to approximately 80 per cent. of capacity.

You will wish to know whether the character of the investigation was not such as to leave room for a vitiating margin of error. We concede that the figure of 80 per cent. as a general average for American industry as a whole is not precise; the true level of operation might conceivably have been as low as 75 per cent. or as high as 85 per cent. The substantial accuracy of this estimate of the amount of economic slack was confirmed by the percentage of increase that occurred in the war time when industry operated at forced draft.

In any case, our first finding was of fundamental importance. The facts showed beyond question that—for some reason or other—the economic system, even in a period of great prosperity, was running at substantially less than a capacity basis. Analysis of the data as far back as to 1900, moreover, showed that such a situation had long been characteristic of American industry.

Step 2. The second task was to determine whether the failure to utilize our productive capacity fully might possibly be explained by any impediments or maladjustments within the *productive* mechanism itself. We were unable to discover any bottleneck, weak link or defective part in the productive machine. That is to say, there was no shortage either of raw materials, industrial plant and equipment, power or fuel, transportation facilities, money or credit or labor, which might explain the failure of the system as a whole to operate on a capacity basis. The source of difficulty had, therefore, to be sought outside the productive machinery.

Step 3. As the next step, we turned to a study of the distribution side of the economic system. Might the difficulty be found in a maladjustment between

productive capacity and purchasing capacity? To throw light on this question it was necessary to show how the national income is divided among the various groups which comprise the body politic.

For this purpose we had available reasonably satisfactory data with reference to the incomes of the American people. We found an extraordinarily wide dispersion in the distribution of income. In the higher ranges, incomes were in excess of any normal consumptive requirements; but the great masses of the population had incomes insufficient for primary requirements. There exists a *potential* demand vastly greater than could have been supplied had we operated our economic system at full capacity. Over the period from 1900 to 1929, the poor were not growing poorer, but richer. But the rate of income growth was, nevertheless, more rapid in the upper strata.

Step 4. The fourth step was to determine the effect of this unequal division of income upon the allocation of the total income as between spending for consumption and saving for investment. We found that the savings of those in income groups below $2,000 were negligible, while those in the higher income brackets saved a substantial percentage of their total incomes. Out of 15 billion dollars of individual savings in 1929, something like 13 billions was made by 10 per cent. of the population. Since the number of people in the higher income groups was increasing, the percentage of the total national income that was diverted to investment channels was increasing.

For this phase of the investigation the data were less satisfactory and precise. The margin of error in estimating the percentage of savings made by the upper income groups might possibly be as great as 20 per cent. Even so, two basic facts were clearly established: First, the great bulk of the savings is made by a small percentage of the population; and, second, owing to the rapid growth of income at the top of the scale, the percentage of the total income that is diverted to savings channels was tending to increase.

Step 5. The fifth step involved a problem of a different character. Granted that the existing distribution of income tends to increase the flow of funds into savings as compared with consumptive channels, does this fact serve in any way to impede the operation of the economic system? To answer this question it was necessary to study the forces which govern the transformation of the money savings of individuals into new capital equipment. This portion of the investigation required, first, analysis, and second, statistical verification. It should be stated at this place, moreover, that our conclusions in this connection are fundamentally at variance with hitherto accepted theories.

According to traditional views the greater the amount of money that is directed into investment channels the better, for it will all automatically be used in employing labor and materials in the construction of new plant and equipment—thereby increasing products capacity, and hence consumption, in the future. It had been assumed that when one saves money he simply exercises a demand for capital goods instead of for consumption goods, and that in consequence the production of the latter would increase, while that of the former would decline. Such an assumption, it will be noted, implied that consumptive demand and the demand for capital goods are independent variables.

Another line of reasoning, however, as well as observation of the actual processes of the business world, suggested that a declining consumptive demand might of itself deter the construction of new plant and equipment, even though funds were available for the purpose. Since new plant and equipment are constructed

with a view to expanding the output of consumption goods, does not consumptive demand constitute basically and ultimately the real demand for new capital? That is, instead of the demand for capital goods being derived directly from the money savings of individuals, is it not rather derived indirectly from the demand for consumption goods?

Conceding the fact that ultimately the profitable use of new plant and equipment depends upon an expanding consumptive demand, it has nevertheless been traditionally assumed that business enterprises would build new plant and equipment even though consumptive demand were declining—in anticipation of an ultimate increase in consumption. To test the validity of this assumption we turned again to the facts as revealed by business statistics. We found, first, that new plant and equipment are constructed in any large way only when consumptive demand is *simultaneously* expanding, and, second, that the rate of growth of new plant and equipment over a period of years is adjusted to the rate of increase of consumptive demand rather than to the volume of money savings that may happen to be available for investment purposes.

It follows from this analysis that the amount of money savings as compared with the amount of consumptive expenditures is a matter of fundamental importance; and since the percentage of the total income that will be devoted to consumptive purposes depends upon the way in which the income of society is divided among the various groups, the distribution of income presents a problem of the utmost importance.

It was stated early in this discussion that the economic system is an evolving organism. The analysis which we have just been making illustrates the influence of changing conditions upon economic interpretation. In former times when incomes were low and few people had large accumulations there was almost always a shortage of investment funds. But in consequence of the higher levels of income now prevailing and its increasing concentration the balance has tipped the other way. Instead of a shortage of funds for investment we now tend to have an excess.

I may add that in the final division of our investigation we have discussed several alternative means of accomplishing the desired end and have indicated the methods by which we think economic progress is most likely to be achieved. Space does not here permit even so much as a recapitulation of this phase of our analysis.

BODY ANATOMIC AND BODY POLITIC

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I

ARE methods of regulation within the human body of any interest to those responsible for regulation within the nation? There is nothing new about this question. It has been often asked and answered by philosophers. Economists have usually sidestepped it, deterred by the fact that the body anatomic and the body politic are not the same, so that comparisons between the two are of doubtful value and may even be misleading. One of our physiologists, Cannon of Harvard, has, however, bravely entered the lists.

The concept of organic evolution deals with the succession of animals and plants on the globe and their mutual relations up to the human body politic. It has been the cause of many a wordy battle between scientists and churchmen. The opposition of the latter and the earnest and sincere loud-speakers on both sides have proved most stimulating, with the result that all educated people to-day know and appreciate the fact that evolution has taken place, though they may differ in their opinion as to the methods employed by nature.

The cell theory, of almost equal importance, according to which all plants and animals are made up of very small individual living units, miscalled cells, is now universally acknowledged to be true in fact. It is, however, almost unknown to the laity and for an interesting reason. Theodor Schwann, a good Catholic, presented the manuscript of his classic paper to the Bishop of Malines for approval before it was published in 1839. Criticism was thus officially disarmed at the outset. The stimulus of resistance was lacking. No heated discussions took place in public. Consequently the public generally has not grasped the significance of this far-reaching generalization.

II

An accurate census of individual cells in the body anatomic has never been made. The estimated number is, however, about 26 million million. The largest is the egg. If a series of human eggs were placed in line side by side, about 250 of them could be fitted in, in a distance of one inch. If they were very dense or strongly pigmented, and the lighting were just right it is possible that single human eggs would be barely visible to the naked eye. But they are neither. All the other cells are of microscopic dimensions. We visualize them as tiny, jelly-like masses of variable consistency, diverse form and usually colorless. All respond to stimuli, but they do so differently, depending upon their habits. They have less freedom and are more "bound upon the wheel" than members of the body politic. The bonds consist of heredity and of physical and social environments.

With certain reservations, the comparison can be carried further. Cells like humans pass through periods of youth, maturity and old age. Each must breathe, have food and drink as well as suitable surroundings. They specialize by learning to do less and less, better and better. The life-span of some is measured in years and of others in days. Thousands are dying every hour, but the body anatomic endures for the traditional threescore years and ten unless the regulation breaks down.

Let us compare some types of cells with the millions of individuals which constitute a fairly self-contained nation for which internal social regulation is a pri-

mary problem. The muscle cells may be likened to the manual laborers. They make up a very large part of our body as the laborers do that of the body politic. The gland cells may be looked upon as manufacturers; since, from crude materials, they make special products of use in the community. The nerve cells are the oldest and wisest. They constitute the ruling class and have special means of gathering information; domestic, from within the community, and foreign, from the outside world. The fat cells have something in common with bankers, since they store potential, not actual, energy and give it up reluctantly on demand. Order is enforced by the leucocytes or policemen. These cells attend to many matters, including the arrest of bacteria that may invade the body. The highways (large arteries) and byways (capillaries) are regularly patrolled by them. Usually they remain in the streets (blood vessels) but, in search for offenders, no part of the body anatomic is immune from entry.

With increase in cellular specialization the birth rate goes down. For example, some cells in the manufacturing group can, by division, produce more cells of the same sort. Not so, the high and mighty nerve cells. As soon as they have learned their duties and have established social contacts with others that they consider on an equal footing, they lose all ability to reproduce their kind. Only by a local social revolution in their class—a neuroma or tumor of nerve cells—can fruitfulness be maintained and then it is of a perverted kind, pregnant with danger for the body anatomic.

Obviously, the body is more than a mere collection of millions of individuals. It has a personality. About this feature there have been many tiresome arguments. Briefly stated, personality results from the memory of, and physical changes caused by, adjustments—both external and internal—between the body and the outside world and between the individual cells that make up the body. So, too, the personality of the body politic is more than the sum of the qualities of all the people in it. Its personality, exemplified by Uncle Sam and John Bull, is conditioned by the memory of, and material changes caused by, external and internal adjustments. The first results from contact with other nations and with the forces of nature and the second from association of individuals and classes within it. Obviously, heredity is also a potent factor in conditioning personality, whether it be of the body anatomic or politic.

III

By experience, through millions of years, nature has evolved interesting methods for regulating and integrating the hordes of individual living cells which make up the human body.

Food taken in from the digestive tract is distributed by the cardiovascular system of transportation to each and every kind of cell, be it noted, not in equal amounts, but according with its needs when working and resting.

Work is demanded from a great many more cells than in ordinary times are needed for the maintenance of the community. Removal of $\frac{9}{10}$ of the adrenal cortex is not incompatible with life. Similarly, it is said that $\frac{1}{2}$ of our lungs, $\frac{2}{3}$ of our kidneys, $\frac{3}{4}$ of our liver and $\frac{4}{5}$ of our thyroid and pancreas can be dispensed with. It is difficult to think of an organ of the body not over-supplied with cells.

The primary division of labor is between classes of cells that have specialized in different directions. In each occupation the work required is assigned to the individuals having in mind first the needs of the body as a whole and second those of the individual. Unemployment, if prolonged, is followed by wasting and death. However, large classes of cells live on the community, with regular duties so light as to be little known and almost unappreciated, but they are ready to help in emergencies. We think at once of the so-called fibroblasts that take part

in the formation of fibers which hold things together and are essential in the architecture of the body anatomic. These cells, as they exist under the adult epidermis amid the proper number of connective tissue fibers, have not much to do. For them to go on rapidly forming still more fibers would be a calamity. In case the skin is cut through, they display very gratifying activity and the fibers, that they help to make, draw the edges together. Muscle (and perhaps nerve) cells exhibit a high standard of service. Though quiescent for considerable periods, when called into action they do their level best. In the words of the physiologist, an adequate stimulus leads to maximum work. Increasing the stimulus beyond this point does not lead them to perform more effectively. When the stimulus is decreased they do not respond. This is the "all or none law" of labor.

The excess of willing hands in every basic occupation is termed the physiological reserve. Engineers have learned, likewise by experience, that they must always provide a factor of safety. They must build a bridge capable of sustaining a heavier load than it is expected to carry, a boiler that will not burst when subjected to a pressure higher than that necessary to supply the head of steam required, and so on. With respect to work, the body anatomic is wiser than the body politic. The task is accomplished by multiplication of single workers. Never is the risk incurred of disrupting established conditions by the sudden introduction of some new invention permitting one to do the work of many.

But aids for effective work are provided in abundance. The use of hinges, levers and plenty of lubrication was discovered long, long ago. Lime is employed in building bone, as in making concrete. Organic material is distributed as needed in bone. And we recall how the Egyptians, in biblical times and even to-day, put straw in bricks. Rubber is an important article of commerce. Elastic tissue, or vital rubber, is employed in varying amounts in the construction of most parts of the body anatomic; but in largest amounts in the vascular system which unifies and integrates.

When human beings in the body politic grow old they tend to be neglected, except in China and some other Oriental lands, where they are highly venerated. With us, they are expected to cease work without remonstrance and to await the end philosophically. To the cry, "I want still to be of some use," a deaf ear is usually turned. Neglect of the aged is an indictment of modern civilization. It is our duty to profit from the many ways that they can serve. Nature is inexorable, but it is not unkind. Many aged and dead cells are not only utilized but are given positions of great importance. Firmly bound together in a dense layer on the surface of the skin, dead epidermal cells act as a shield and protect the living cells within. Without this thin, delicate and flexible covering the body anatomic could not endure. Nature has arranged for another category of dead cells to carry life-giving oxygen to all the rest. Until they die, red blood cells perform no useful service. Their entire life is shaped so that they may serve after death. By dying as they do their corpses acquire physical and chemical properties which lead to the absorption of oxygen in the lungs and the subsequent liberation of oxygen throughout the body.

Rest is mandatory, for without it the working billions of cells would soon fail. But the time allotted to recuperation differs with the occupation. Laziness is not permitted. Mischief makes for idle hands to do. To give freedom, after a standardized eight- or ten-hour working day, is not the way of nature. The well-being of the body anatomic is the main and only consideration. For some rest comes, or should come, with darkness. We think at once of the cells of the eye, of the skeletal muscle cells by which we

move and of the nerve cells that direct them. These, and many others, are the day laborers. The system of transportation for the distribution of crude materials and finished products is never allowed to lag. Cardiac muscle cells rest for about 15 hours in the 24; but they snatch their rest in very brief periods, as ordered. The muscles of respiration must likewise be content with momentary relaxation. Removal of waste, as performed by the kidneys, depends to some extent upon the intake. With them, there is evidence that some groups of cells (the glomeruli) operate in shifts —a method frequently adopted for individuals making up the body politic.

A suitable environment in which to work and rest is as necessary for cells as for individuals. Sudden and radical changes must be avoided. Responsibility rests on government in the body anatomic, and on the cells themselves, as classes among which the labor is divided. It is the duty of government to supply through the system of transportation (blood stream) vital necessities and optimum amounts of crude materials needed in the several occupations. Special methods are employed to regulate the quality of the supply so that it shall be uniform and not subject to dangerous fluctuation. It is the duty of the groups of cells, relying on this help, to continue their labors without interruption. Since their functions are diverse, comprising all those necessary to the welfare of the community, and because individuals in like occupation are naturally associated, there is superposed upon the basic, unifying and stabilizing influence of wide distribution of vital necessities and materials a local diversity. Thus, the local environment of the manual laborers grouped in the muscles differs from that of the manufacturers grouped in the thyroid gland. Each, by requiring rather different materials, in addition to vital necessities, by working in a different way and by developing distinctive associations makes inevitably a different environment. Farm laborers create for themselves different surroundings, both physical and social, from those inevitable in an industrial center. Take the nerve cells. They occupy two strata in society within the body anatomic. One is lower, mingles more intimately with the general population and behaves more automatically; while the other is higher, directs more or less consciously, and, holding itself aloof from the common herd, occupies a sheltered and privileged position in the brain and spinal cord guarded by strong bony walls. A serious disturbance may arise, either from deficiency or surplus, in the government-run system of supply or from a change in the local environments occasioned by failure of groups of cells to provide stability therein by not attending to their duties.

IV

It will be observed that the cells of the human body are aquatic, since they live as small groups or communities in a watery environment regulated by the blood stream and their own individual efforts. The human beings of the body politic, on the other hand, are outwardly terrestrial and live on dry land. But, thanks to Darwin and the others, encouraged and strengthened by spirited opposition to their views, it is now generally accepted that we humans have developed from animals who were inhabitants of the ocean. All these ages we have carried parts of the watery environment with us. Those who by chance read these words do so by looking through thin films of salt water supplied by the lachrymal glands. If these vestiges of the original watery environment of the body politic were allowed to dry up blindness would ensue. They may throw the book away with a sigh of relief, in which event they find momentary refreshment by increased absorption of atmospheric oxygen, again through a thin layer of salt water lining their lungs. Later on, they may listen with approval to criticisms of

the wild ideas expressed in this paper; but they can do so only by using little bodies of salt water which constitute essential parts of their inner ears. Our forgotten ancestors learned to see and to breathe and to hear in salt water and we must perforce do the same, so that we are at least partly aquatic. To express it differently, the surfaces of our bodies in contact with air are all coated with dead cells (skin, hair and finger nails). The surfaces, external and internal, made up of living cells (cornea of eye, inner ear, lungs, digestive, urinary and reproductive tracts) are all wet, *i.e.*, aquatic.

Physiologists are very positive about the importance of the fluid cellular environment. Consideration of the totality of circulating fluids in the body led Claude Bernard in 1878 to make the statement that "all vital mechanisms, however varied they may be, have but one object, that of preserving constant conditions of life in the internal environment." This is one of the truly great conceptions in biology, though the constancy is not so rigid as he thought. It is subject to slight but significant changes in pregnancy, for example. In the analysis of the mechanisms, Cannon and his associates have taken a leading part. Many of the regulated properties, such as temperature, acid-base equilibrium and pressure, are without evident parallel in the body politic. It is the control of deficiency and surplus that is instructive. Freedom from sudden change in the amounts of substances in the internal fluid environments is provided by regulation of production, by storage, by elimination of surplus and by efficient distribution. The body politic has quite independently discovered the same methods. The trouble is that it fails to use them properly.

V

We are concerned with production in so far as it involves increase or decrease in materials in circulation. This may happen from over-eating, under-eating or from disturbances in assimilation or excretion. Normally it is not brought about by failure to regulate domestic production by glands and other tissues. In the body politic conditions are somewhat reversed. Imports are frowned upon, not because by their addition surpluses are created, but because they are unwelcome to certain classes in the community. In other words, the well-being of a part is placed before that of the whole—a condition rare indeed in the body anatomic. But it is chiefly in the regulation of production of crude and manufactured materials that the body politic fails. Instead of humanizing the Bureau of Standards and of developing, as nature has done in the body anatomic, mechanisms by which slight increases or decreases in the materials in circulation are quickly detected and the activity of the cell groups responsible is promptly adjusted, we have obeyed the command of Lao Tzu, "let matters take their own course and do not interfere," for we prized our own liberty and wished also to guard that of others. Nature, on the other hand, does not recognize individual rights and is far from being sentimental. Confronted by surpluses the administration has courageously attempted to reduce production, but in doing so the aid extended to the producers by artificial increase in price through curtailment of output has worked a serious hardship on the rest of the body politic.

Another way to care for at least part of the surplus is by storage. This setting aside until needed is an act of survival value. The body anatomic stores part of the excess of ingested foods against the time when they may be required. But storage is not resorted to until the amount in the circulation, being distributed effectively to all parts, is more than enough. Thus, fat is stored chiefly in the subcutaneous tissue, carbohydrate in the muscles and liver, protein in the liver, calcium in the bones and various other substances in appropriate locations. The

chance of failure to find water is not so great. Therefore water is stored only to a small degree. Oxygen, another prime essential, is present everywhere in the air. The contingency of having to do without it does not have to be faced. Consequently no arrangements are made for storage. When more materials are needed by the cells, which for some reason are called upon to work harder, they take more from the blood stream. To compensate for this loss, increased amounts are simply released from storage and circulated without the formality of requisitions in triplicate to be approved by a long line of officials. The release is so prompt that a serious deficiency in the blood stream is prevented and the release is so quickly inhibited at the right moment, that a marked surplus is not created as the unusual demand is satisfied.

The body politic may also horde imports for use when required. Surpluses in domestic production, curbed as we have seen in the body anatomic, constitute a serious difficulty, mainly on account of the inadequacy of the system of transportation. To store, as a remedy for local surplus, before the legitimate demands of the entire body politic are met, nature would call bad management. It is worse to use the device of storage to serve a particular group concerned in the production of a special commodity and by withholding it from the majority to make the majority pay an increased price for something that they must have. True, the idea was to increase the purchasing power of those not favored by the experiment so that they would not suffer unduly. To have both effects produced at the same time was more than could be expected and did not happen. The body anatomic would never interfere so radically.

Elimination of actual surplus is practiced without compunction by the body anatomic. Products of digestion not needed to maintain the all-important constancy in properties of the blood stream and not used for storage (because to push storage to an extreme would be unwise) are simply eliminated by the kidneys. The body politic has been known to act hastily in the disposal of apparent surpluses. The word "apparent" is used, because a very noticeable local surplus may exist in the absence of an actual surplus in the nation considered as a whole. It may even occur in one part of the country while there is a serious deficiency elsewhere. If our body politic had possessed a centralized, properly controlled and operated system of distribution or transportation, comparable to the cardio-vascular system, local surpluses would be as rare as in the body anatomic and we should not have to explain the burning of grain in Kansas, urgently demanded in industrial areas; the allowing of oranges to rot in Florida, which could be used to great advantage elsewhere; and the letting of coal heap up at the mine heads, while people suffer from the cold in other parts of the country. Evidently transportation of essentials in the body politic, as in the body anatomic, must be maintained and directed for the benefit of all at the expense of all, each paying according to his ability.

Electricity is a new plaything and money-getter in the eyes of the body politic. We are just beginning to realize its uses. Nature is a long way ahead. From the beginning of life on the earth living cells have been constructed as electrical engines. No cell in our body could function, nor even exist, if electrical changes in it were shut off. Rapid integration by the nervous system (telephone and telegraphic systems) would cease. The muscles (heavy industries) would no longer operate. All glands (factories) would stop. Death would be complete and in this case instantaneous for all cells in the body. Life-giving power must be made available to all (not simply to a privileged few) in the form

of an uninterrupted supply of necessary materials via the blood stream. The declaration of policy of the Tennessee Valley Authority, that " . . . the interest of the public in the widest possible use of power is superior to any private interest, with the result that in case of conflict, the public interest must prevail," is sound biologically.

VI

The human organism can well be admired as the noblest of creations, but it is not a perfect mechanism. We have limited ourselves to a consideration of an average, healthy specimen. Regulation of production in the body anatomic sometimes fails. For the manufacturers in the thyroid to produce and throw on the market more than is needed causes Graves' disease, sometimes termed exophthalmic goiter because the eyes protrude. The unfortunate individuals are geared up to a higher rate of activity than they can stand. Conversely, when the product is available in insufficient quantities, there is marked lethargy. Many other examples of too much and too little activity might be cited.

That about one in every four humans dies as a result of some form of cardiovascular disease should be an object lesson to physicians and statesmen alike. It will be said that death of the body politic through failure of the corresponding transportation system does not take place, for the human race flows on. But for some reason, the bodies politic of ancient Rome, of the Incas, Mayas, Czaristic Russia and a score of others have disappeared, despite the survival of descendants of individuals. Devastating diseases and changes in climate, rendering life in the occupied areas much more difficult, have been prominently mentioned as factors. In order that the race may continue individual cells of the bodies anatomic, the eggs must also survive its death and leave descendants. When the circulation fails and consciousness is lost the individual is pronounced dead. This is true as far as the individual is concerned, but some of the cells of the body continue to live for varying periods. The heart has been made to start beating again in executed criminals. Nerves remain alive, for by their stimulation muscular contraction is produced. Lewis and McCoy of Hopkins have found that in animals left at room temperature some kinds of cells may survive for 120 hours. If given a fair chance many of them are able to continue living. All that is required is to remove them quickly from the dead (!) body and place them in specially prepared fluids. There is good reason to believe the cells cultivated in this way outside the body will continue to multiply and produce their kind as long as the fluid environment is suitable and the excess growth is removed. The most obvious difference between death of the body anatomic and failure of the body politic to survive is the regularity and inevitableness of death in the former, whereas the particular social organization that characterizes the latter may last for a longer or shorter time, depending on circumstances. The disintegration and decay of human beings and of nations is brought about in many ways.

Ranking perhaps next to failure of the transportation system is antisocial behavior of special groups. One in every ten of us dies of cancer. The nature of cancer is shrouded in mystery and its real remedy still unknown. Nevertheless, there is an almost worn-out simile. Often, when the body anatomic attains maturity, rarely in youth, some cells display a dangerous irresponsibility to the welfare of the whole. They shake off community control, pilfer the food of others, invade their homes and increase in number without restraint. Particularly serious it is if this happens in some location hidden deeply within the body. When the malignant cells force their way into the blood stream (or lymphatics) and are distributed throughout the body the outlook becomes hopeless.

In the body politic a process analogous,

though of course only superficially so, may occur. It is not so likely to be manifested in a young and vigorous nation busy expanding geographically and in other ways as in a more mature and settled community in which individuals have time to harp upon their troubles. Here, also, irresponsibility may develop and antisocial tendencies, likewise an overpowering urge to be done with the particular sort of national control that irks. The malcontents at first create merely a local disturbance in the submerged part of society and are little appreciated by the body politic. They do not take time to increase in number by multiplication, as the cells do. Instead, they try to persuade others to join them, generally, without much success, despite the appeal "take from those that have and give to those that have not." But their strategy is not very different from that of the cancer cells. If they can gain control of the system of transportation and use it freely to spread their doctrines a violent upheaval is almost inevitable.

Fortunately much may be done to save the day in the body anatomic as well as in the body politic by early recognition of what is taking place. It is to be observed that both the cancerous change, and the anarchistic one, frequently follow some kind of repeated irritation or injury. Neither cell nor individual can, as a rule, be accused of embarking upon this mad career without provocation.

VII

Such breakdowns emphasize further the importance of stability of environment for the cells in the body anatomic and for the people in the body politic. The price paid in the body anatomic is loss of freedom. It is in no sense a democracy, nor even a kingdom. The individual cells live and die for the benefit of the whole state, and most of them must stay put in the position to which they have been called. Existence, except as part of the state, is ordinarily out of the question. Nature has been careful to treat all cells of the same class equally with respect to food, labor demanded and rest as well as living quarters. This equality within a given class is an object lesson for the body politic. On the other hand, class distinctions are maintained rigidly and without exception, for without them specialization and division of labor could not be provided. Evidently class distinctions are equally essential in the architecture of the body politic.

The integrity of the body anatomic is also paid for by regulation of reproduction of individuals. When the optimum number in each class is reached birth control is enforced. And, again, this additional class distinction is imposed for the benefit of the body as a whole. The principle adopted is that in each class reproduction shall compensate for inequality in death rate. The body anatomic is the product of long years of evolution, while the body politic is a new creation. Not until we get over the relatively brief phase of geographic expansion and the populations of the various nations are forced into equilibrium, with but little increase or decrease in number, can we look for much in the way of real social democracy. It is possible that those nations will lead, in respect to the welfare of their citizens, if not in material power and glory, that attain internal equilibrium first. Sweden, for instance, is to be congratulated on the beginning she has made.

BASAL FACTS IN THE HISTORY OF MATHEMATICS

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UNDER the entry "algebra" in the second edition (1934) of Webster's "New International Dictionary" there appears the following striking statement, which relates to the experiences of a large number of educated people: "The essential difference between arithmetic and algebra is that the former deals with concrete quantities while the latter deals with symbols whose values may be any out of a given number field." In view of this quotation from a work which is now widely used in our schools it may be desirable to emphasize the fact that it is impossible to prove that arithmetic now deals relatively more with concrete quantities than algebra. For instance, the ordinary multiplication tables deal entirely with abstract numbers and the first table in the ancient Egyptian work entitled "Rhind Mathematical Papyrus" (about 1700 B. C.) deals also entirely with abstract numbers. One of the basal facts of mathematical history is that the mathematical literature which has been preserved from the past ages is relatively about as abstract as that which is now being written.

There is no clear line of demarcation between arithmetic and algebra. Various developments are sometimes classed with arithmetic, while at other times the same developments are classed with algebra. For instance, the theory of determinants has sometimes been treated under the heading of arithmetic, while it is now more commonly regarded as belonging to algebra. The theory of equations is usually regarded as a characteristic subject of algebra, and the number system of algebra is commonly regarded as more general than that of arithmetic. In fact, there is an evident tendency towards generalization as one advances in mathematics, but there is no definite evidence of a tendency towards dealing with a relatively large number of abstract notions in modern mathematics than in the extant older developments of our subject. In both pure and applied mathematics there are many evidences of progress, but the relative extent of these developments does not seem to have changed much during historic times. It has recently been pointed out by O. Neugebauer, Copenhagen, Denmark, that even the ancient Babylonians used negative numbers, but they did not understand the theory of these numbers in the modern sense.

These recent discoveries relating to negative numbers imply that these numbers were gradually developed during a period of more than three thousand years before a satisfactory theory thereof was published. The fact that their use in applied mathematics still sometimes presents difficulties can be seen from the following striking quotation from the writings of an eminent scientist and winner of the Nobel prize (1921): "I have tried, in other fields, to show the incredible confusions, of which the whole world is now one seething example, that have followed from the invention by the Hindu mathematicians of negative quantities, and their justification from their analogy to debts."[1] No such confusions exist now in pure mathematics as regards the use of negative numbers, but when these numbers were finally adopted it became necessary for the pure mathe-

[1] F. Soddy, "The Interpretation of the Atom," preface, 1932.

maticians to abandon some views of long standing, including the view that the ratio of a larger number to a smaller number always exceeds the ratio of a smaller number to a larger, since $3/2=-3/-2$ and 3 is larger than 2 while -3 is smaller than -2.

A basal fact in the history of mathematics was expressed by F. Klein (1849–1925) in the following words: "Think of it; one of the greatest advances in mathematics, the introduction of negative numbers and of operating with them, was not created by the conscious logical reflection of an individual. On the contrary, its slow organic growth developed as a result of intensive occupation with things, so that it almost seems as though men had learned from the letters."[2] The utility of some mathematical advances sometimes forced these advances on the mathematical public before a satisfactory theory for these advances had been developed. The extension of the number concept so as to include ordinary complex numbers may also be said to have forced itself on the mathematical public long before a satisfactory theory of these numbers had been published. One of the almost mystical elements of the development of mathematics, which was unobserved for a long time, is that when an unknown becomes involved in the form of an algebraic equation of degree n it associates with itself $n-1$ other unknowns which may have some quite different properties but for the solution of this equation are equivalent to the given unknown.

It should be emphasized that the history of mathematics in so far as it is based on written evidences extends over a period of only about six thousand years and that very little is known in regard to the mathematics of the first thousand years of this period. Mathematical chronological tables which extend to earlier periods are based on indirect evidences and hence they are of doubtful historical value. The main fact in this connection is that the earliest mathematics which is extant is somewhat advanced. In the Babylonian countries it includes at least partial solutions of the quadratic equation by completing the square just as is done in modern times, and the partial solutions of equations of higher degrees, including the sixth, by methods which differ from those now commonly used. In Egypt it includes the determination of the volume of the frustum of a square pyramid by a method which is still in use. Hence it results that a considerable part of the early developments of mathematics will probably never be accessible to the student of the history of our subject.

A somewhat curious fact is that the reliable history of the most ancient mathematics is now the most recent mathematical history and relates mainly to Babylonian and Egyptian mathematics. The most extensive data relating to ancient Babylonian mathematics were published in 1935 under the title "Mathematische Keilschrift-Texte" and appeared as volume 3, Abteilung A, of the periodical called *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik,* which was started in 1930 and appears irregularly. Considerable has been published in regard to the ancient Chinese mathematics and the ancient Hindu mathematics, but very little of this material is now regarded as reliable by the critical mathematical historians. Much of the history of the mathematics of the ancient Greeks is also unreliable and has been greatly modified in recent years. The works of Euclid, Archimedes and Apollonius exhibit, however, very great advances beyond those of the earlier writers on our subject.

A characteristic feature of the mathematics of the ancient Babylonians is that

[2] F. Klein, "Elementary Mathematics from an Advanced Standpoint," pages 25 and 27, 1932. Translated into English by E. R. Hedrick and C. A. Noble.

they developed a positional arithmetic to the base 60 in which two numbers which differ from each other only by the fact that one is a power of 60 times the other are represented by the same symbols. By means of this notation they could treat fractions in exactly the same way as integers when they are combined according to the fundamental operations of arithmetic. Their method was similar to our modern method of using decimal fractions, with the exception that they did not use a symbol corresponding to our decimal point and hence they did not employ either initial or terminal zeros. This system of numerical notation is unique in the history of mathematics and it is of great interest because it points to the possibility of using numbers merely as representatives of geometric series with a common ratio which is equal to the base of the number system. By this method each such progression is represented by the same numerical notation and each such notation represents any one of the numbers in the same series. This is a very remarkable system of numerical notation.

These recent discoveries relating to the ancient Babylonian mathematics exhibit the fact that general histories of mathematics are apt to be soon out of date along certain lines and hence they should be used only in connection with the recent periodical literature dealing with the same subjects. There probably never before was a time when such important modifications as regards mathematical history became necessary in such a brief period of time as during the last two or three decades. This does not imply that former general histories on our subject have become useless, but that they should be used cautiously and in the light of where recent progress has been made along the line of mathematical history. Unfortunately, many of the general histories on our subject failed to embody various recent advances at the time when they were published. This is especially true of most of those which appeared in the English language, including American publications. Even a decade ago no one knew that the ancient Babylonians had made important advances in algebra.

The ancient Greeks seem to have been the first to take an interest in the history of mathematics. As far as we know now the earlier writers regarded mathematics as an impersonal subject for which no individual deserved special credit but which was common property just as the air we breathe. The idea of discovering mathematical truths to be transmitted to all future generations as an enrichment of their intellectual heritage does not seem to have engaged the attention of the predecessors of the ancient Greeks. Even the "Elements" of Euclid contain no historical references, and this example was followed by many later writers. On the contrary, Archimedes says near the opening of the first book of his work on the sphere and cylinder, in speaking of Eudoxus with respect to the volume of a pyramid, "For these properties also were naturally inherent in the figures all along, yet they were in fact unknown to all the many able geometers who lived before Eudoxus, and had not been observed by any one."

Mathematics involves thousands of theorems and methods which have not been traced to their origins in the extant literature. General mathematical histories therefore deal with selected sets of results which are supposed to be of special interest. The large German mathematical encyclopedia, which began to appear in 1898 and was announced as completed in 1935, aimed to include the historical development of the mathematical methods since the beginning of the nineteenth century. It also aimed to devote the last of its seven proposed volumes to history, philosophy and didactics, but unfortunately this volume was abandoned, and hence we do not as

yet possess an encyclopedic treatment of these subjects on a large scale. The fact to be emphasized in this connection is that in view of the enormous extent of the available material the general histories of mathematics have restricted their attention to a comparatively small number of facts. A complete history of mathematics is impossible not only on account of the serious gaps in our knowledge but also on account of its extent.

Elementary mathematics has become a kind of thought currency which is used for its convenience by many who do not consider its real nature, just as in financial transactions people use the currency of the land without always considering the basic principles which give value to it. The history of mathematics can not be fully understood without bearing in mind that there is a wide difference between learning to use mathematics in the solution of problems and mastering the fundamental principles of the subject. The pre-Grecian mathematics which is extant consists almost entirely of the solutions of particular problems, and it seems very unlikely that many of those who learned how to solve these problems interested themselves in securing an insight into the reasons why correct results were obtained in the given manner. An important source of mathematical progress is that many rules used to solve special problems were later seen to be much more general than these special problems indicated.

Another analogy between business and mathematics is that the literal constants in formulas correspond to the blanks left vacant in business forms. The numerical values of these constants have to be supplied before the given formulas apply to individual cases just as the blanks in a business form have to be filled in before it is useful in an individual case. Historically it is of great interest to note that mathematics did not reach this blank form stage until about the time of F. Vieta (1540–1603). The formulas which became possible by the development of the algebraic notation effected the same kinds of economy in mathematical work as are effected by the forms with blank spaces in business. The use of the former as well as that of the latter seems to have increased rapidly in recent times. The observations which apply to the general algebraic equations may be compared with the observations which apply to all deed forms to property before the blank spaces have been filled in so as to individualize these deeds.

From the standpoint of accuracy the situation of the history of mathematics in our schools is almost pathetic. This subject is now most commonly taught where the facilities to become acquainted with recent advances in it are meager and by means of text-books which failed to embody many of the advances at the time of publication. According to a recent article[3] 42 per cent. of the teachers colleges and normal schools in the United States of America offered then courses in the history of mathematics, while only about 26 per cent. of the colleges and universities offered such courses. What is more important in this connection was recently stated by President J. B. Conant, of Harvard University, in the following words: "If our young men and young women are to have an understanding appreciation of the spiritual values of the civilization which they inherit, they must be given an account of the historical development of our knowledge and of our philosophy. The history of science, the history of ideas, the history of scholarship and the history of universities should now be occupying the attention of many instead of a few. A discussion of these subjects with the proper emphasis on their relation to social and political history might well form an important part of a liberal education, but

[3] A. W. Richeson, "Scripta Mathematica," Vol. 2 (1933–4), page 16. Very meager prerequisites are commonly noted for the students who take these courses, as is noted in this article.

to find satisfactory teachers for such subjects is now almost impossible. Until we have an adequate survey of our intellectual history we can not expect the world at large to understand the importance of the scholar's contribution to civilization."[4]

The fact that it is now almost impossible to find satisfactory teachers of such subjects should be especially emphasized in this connection. It is equally true that it is now almost impossible to find satisfactory text-books along this line. Hence in most cases we find the combination of an unsatisfactory teacher with an unsatisfactory text-book and naturally the result is also unsatisfactory. The most hopeful thing along this line is that students continue to manifest an interest in this subject wherever they are not too strongly impressed with the idea that all their available time is needed to become sufficiently familiar with some narrow field to secure therein the Ph.D. degree. The example of the new Ph.D. degree at Harvard University may exert a wholesome influence on the other universities of our land. At least it is desirable to emphasize the need of becoming acquainted with the many advances which appeared in the periodical literature of recent years and the need of supplementing the text-books by means of these advances.

Mathematics is unbounded, undivided and undefined. Among the mathematical ideas those of number and geometric figure have supplemented each other since the times of the oldest records. The ideas of equation and function appear also in the oldest extant mathematical literature. The latter appears in the rules for the areas of triangles and rectangles in terms of their sides and altitude, and the area of a circle in terms of its diameter. The idea of the limit of an infinite geometric series whose common ratio is less than unity appears in the works of Aristotle and Archimedes, and the explicit formulations of the concepts of function and group appear towards the close of the seventeenth and eighteenth centuries, respectively. These six fundamental mathematical notions underlie most of the later mathematical developments. The idea of limit assumed an especially prominent place when the subject of the calculus began to be vigorously developed near the beginning of the eighteenth century. The first text-book on this subject appeared in 1696 under the title "Analyse des infiniment petits," by G. F. A. de l'Hospital.

Many of the advances in the history of mathematics as well as in mathematics itself have been due to the repeated correction of errors. In a recent book by the well-known Belgian mathematician, M. Lecat, entitled "Erreurs des Mathématiciens des origines à nos jours," 1935, the following names are included among those who committed errors in their publications: N. H. Abel, A. L. Cauchy, A. Cayley, R. Descartes, L. Euler, K. F. Gauss, J. L. Lagrange, S. Lie, I. Newton and H. Poincaré. All these names appear also in this work among those who corrected errors in a public manner. This implies that some of the most eminent mathematicians of all times have taken part not only in the removal of errors which appear in the published literature but have also not always been sufficiently cautious to avoid the committing of errors in their own work.

The lasting reputation of a mathematician is based upon a kind of residue after his harmful publications are subtracted from those which have proved to be useful. There is a great difference as regards the discredit due to erroneous publications. When these relate to the newer fields where advances are extremely difficult, very useful work has often been done by those who proceeded without awaiting the building of safe

[4] "A New Ph.D. Degree at Harvard University," SCHOOL AND SOCIETY, 41: 639, 1935. This degree is to be given for work in the history of science and learning.

roads. For instance, in the work noted in the preceding paragraph it is stated, page IX, that the greater part of the researches on the calculus of variations before 1870 involves methods which are inexact or insufficient. Similarly, the early lists of groups were often very incomplete and involve faulty methods. Such errors are commonly regarded with a great deal of tolerance. Similar errors in the recent literature on these subjects would, however, appear as intolerable as the inclusion of the name of Gilbert in the following list: Galileo, Kepler, Gilbert, Napier, Fermat, Descartes, Pascal, Huygens, Newton and Leibniz; and the statement that John Farrar (1779–1853) "did much for elementary mathematics in this country through his translations (1818–1825) of the works of Euler, Lacroix, Legendre and Bézont, and through his publication of a number of textbooks."[5]

To understand the shifting of interests in the development of mathematics it is necessary to bear in mind that there are fashions in the mathematical world as well as elsewhere. To have a work accepted as correct and novel requires only that it fulfils certain conditions which can usually be easily applied to it, but if it is to receive special attention and to secure for its author special recognition it must meet also external situations which are frequently biased and unfair. There have been many so-called schools of mathematicians of great influence in which undue attention was paid to those who cultivated its temporary fads. In our own country these centers of undue influence have been less pronounced than in Europe and have shifted from time to time as its leaders either died or abandoned their positions. Fortunately, there are, however, also subjects, such as differential equations, in which the interest is more lasting and work of high merit has usually been recognized independently of its source. Meteoric reputations in mathematics have not been very common in the supposedly well-informed circles.

[5] D. E. Smith and J. Ginsburg, "A History of Mathematics in America before 1900," pages 13 and 96.

FIFTY YEARS OF INDUSTRIAL ALUMINUM

By Dr. HARRY N. HOLMES

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ALTHOUGH aluminum was first isolated in 1825 by Oersted of Denmark, the entire world production prior to 1889 was but little more than 100 tons, according to Packard in Census Bulletin No. 79.

It is not too much to assert that when young Charles Martin Hall, just fifty years ago this February 23d, discovered the present commercial process of producing cheap aluminum he really gave the industrial world this extraordinarily useful metal. The infant industry, squawking feebly in its swaddling clothes in the Smallman Street factory, Pittsburgh, grew rapidly from a daily production of 50 pounds at the end of 1888 to an annual world production of 600,000,000 pounds.

Equally sensational has been the price range from the impossible $160 or more per pound due to Wöhler, the $27 secured by Deville in 1856 and his final record low of $12 per pound, and the $6 due to Castner's work in 1886 to the present 20 cents per pound due to the invention of Hall and the technical enterprise of his company.

It is remarkable that the most common metal in the earth's crust was so long delayed in its arrival on the industrial stage. Although every claybank is an aluminum mine, as Deville said, the great chemical stability of aluminum oxide was a hurdle too high for the most agile scientist to leap—until 1825.

Then Oersted, famed for his fundamental research in electricity, freed the metal from chlorine in anhydrous aluminum chloride by heating with the extremely active metal potassium:

$$AlCl_3 + 3K \rightarrow Al + 3KCl$$

Wöhler, at Göttingen in Germany, one of the greatest scientists of his time, learned of Oerstedt's work but failed to reproduce his results. Wöhler varied the method slightly by using potassium instead of potassium amalgam and succeeded in preparing a black powder which proved to be aluminum. So tremendous was Wöhler's prestige that, for a century, the world gave him credit for the original isolation of aluminum. Even the scholarly Deville, professor at the Sorbonne, joined in this tribute.

Poor Oersted made the mistake of publishing his research in an obscure Danish journal, where it lay buried until his countrymen, a hundred years later, forced it upon the world's attention. Chemists of the Aluminum Company of America followed the directions given in this old paper and successfully duplicated Oersted's results, something that the brilliant Wöhler failed to do. It is now in order for the world to atone for injustice by giving the Dane credit for the discovery of aluminum.

On the other hand, Wöhler deserves much credit for bringing the new metal to the attention of the world and for valuable research on the properties of aluminum.

The eminent French chemist, Deville, lowered the cost in 1854, by the simple substitution of the cheaper metal sodium for potassium in attack on a mixture of aluminum chloride and sodium chloride.

$$AlCl_3 + 3Na \rightarrow 3NaCl + Al$$

Within two years, by 1856, the price of the metal dropped from $90.00 per pound to $27.00 and by 1860 to $12.00.

Sir Humphry Davy made earlier attempts than Wöhler's to reduce the oxide and failed, as did Silliman. Berzelius,

the eminent Swedish chemist, almost succeeded in anticipating the success of Wöhler when he heated cryolite, the double fluoride of aluminum and sodium, with potassium. Unfortunately, he used an excess of potassium and got an alloy of aluminum with potassium. Had he used an excess of cryolite, Berzelius would now be given credit for presenting aluminum to science.

Henri Sainte-Claire Deville in Paris, famous French chemist, had the financial support of the Emperor Napoleon III in his efforts to take aluminum out of the aristocracy of precious metals into the democratic brotherhood of copper, zinc, lead and tin. In spite of his best efforts Deville complained that the new metal cost a little more than silver.

Where Oersted and Wöhler failed to get anything more metallic than a black powder or a pinhead-sized particle (at least until 1845) Deville made a great advance by coalescing this powder into liquid metal in a stream of hot vapors of anhydrous aluminum chloride. The sodium impurity was removed in a low-melting double chloride of sodium and aluminum.

In 1855 Deville confirmed the findings of Rose and of Percy that Greenland cryolite, a double fluoride of aluminum and sodium, could be reduced to the desired metal on heating with sodium. For good French economic reasons connected with the tariff or tax this method was discarded and the earlier method of heating anhydrous aluminum chloride with sodium was employed.

By a strange turn of the wheel of fate a certain cryolite experiment of Deville's was discussed at length in 1893 before Judge William Howard Taft, later President of the United States.

It occurred to the ingenious Frenchman that he might with advantage electrolyze cryolite melted with sodium chloride since metallic sodium would be secured by electrolytic decomposition of the common salt. The hot sodium thus formed, he hoped, would reduce the cryolite to metallic aluminum. Whatever the mechanism, he won—but not commercially. He abandoned the electrolytic process.

The first object of art made of aluminum was a rattle for the Prince Imperial, ordered by the Minister of State and the House of the Emperor. Napoleon III was said to wear with pride a helmet of aluminum. Now this exclusive royal privilege has been brought into the kitchen, where the once-precious metal caters to plebeian tastes. Although from 1860 to 1880 France was yearly producing a ton and a half of the metal its cost limited it to the trade of jeweler and goldsmith. These artisans soon learned that an alloy containing 2 per cent. copper was easier to engrave. Foucault, of pendulum fame, anticipated the plans for our giant 200-inch reflecting telescope by using a curved aluminum surface for reflecting telescopes, yet he never realized that this metal can reflect over 80 per cent. of incident ultra-violet light.

Deville felt called upon to reassure the public as to the safety of eating food with aluminum forks and spoons. He must have succeeded, for it is reported that Napoleon III at a state dinner had the most distinguished guests served on aluminum plates, while the small fry dined on plates of pure gold.

Like the will-o'-the-wisp, the goal of aluminum for common use continued to remain just out of reach until about 1885 when Castner cheapened the manufacture of sodium (hitherto necessary in producing aluminum) so radically that the cost of the latter metal was cut to $6.00 per pound, perhaps less. And then, just as Castner was about to reap his reward, Charles Martin Hall made sodium unnecessary—and rang up the curtain on the age of aluminum.

Hall was a studious, serious-minded

son of a minister in the college town of Oberlin, Ohio. Even in his high school he was always dreaming of his great inventions for humanity — and trying them. It was most fortunate for Hall and for Oberlin College that in 1880 Frank Fanning Jewett accepted the chair of chemistry and mineralogy, bringing to the work a training equal to the best of that time. A Yale graduate, he had gone to Germany, where, in the University of Göttingen, he was one of the small group of American students who at that time specialized in chemical work under highly trained German teachers.

Most fortunately for young Hall, and for a great many people in this world, Professor Jewett took a fancy to this keen student and invited him into his private laboratory, where for years they worked together on inventions. In those days a routine course in chemistry occupied less than a year, but Hall was given years of special attention by one of the best-trained chemists in the America of that time. Careful plans of attack on aluminum, encouraged by Jewett, were laid by Hall, but they all failed. The boy graduated in 1885 and refused to admit defeat. With home-made contrivances and batteries borrowed from the Oberlin chemistry department the lad struggled on in the historic woodshed against the back of his father's house in Oberlin. He was constantly going to Jewett with his troubles for advice and receiving invaluable help. At last on February 23, 1886, this boy of twenty-two years succeeded where many of the world's eminent scientists had failed.

Yet his discovery was no accident, but rather the climax of logical planning. He searched for a non-aqueous solvent for aluminum oxide and found it in melted cryolite from Greenland. Jewett was mineralogist as well as chemist, and it may well be that cryolite was his vital suggestion. The next step was to find by "trial and error" if this solution of aluminum oxide in fused cryolite would conduct electricity. It did—but no metal resulted. Then Hall discarded his clay crucibles and tried a carbon crucible. Success resulted at once.

Hurrying over to the chemical laboratory with the scarcely cooled little buttons of the precious metal in his palm, he held out his hand to Professor Jewett and said, with ill-concealed eagerness: "Professor, I've got it!"

After three unsuccessful attempts to secure the cooperation of industry and a delay of over two years Hall at last found a haven in Pittsburgh with Captain Alfred Hunt and a small group of metallurgists, who put up $20,000 as capital for the new Pittsburgh Reduction Company. Beginning in late 1888 with a modest daily production of 50 pounds, the business grew to substantial proportions in three or four years.

This success attracted infringers of the Hall patent, and in 1892 suit was brought against the Cowles Electric Smelting and Aluminum Company, of Lockport, New York. It was true that, for a few years, the Cowles Company had reduced aluminum oxide with carbon in an electric furnace, but this was a thermal, not an electrochemical, reaction, and a copper alloy resulted.

Deville's electrolysis of cryolite mixed with salt was cited as antedating Hall's discovery, but the difference was that the great Frenchman did not dissolve aluminum oxide in melted cryolite—and that Deville discarded the process as a failure. Judge William Howard Taft in a Circuit Court of Ohio decided in favor of Hall, January 20, 1893.

As it happened, Hall was employed for a year (July, 1887–July, 1888) by the Cowles Company and gave them an option on his patents, which they dropped with great lack of interest. His discovery was made nearly a year and a half before his contact with this group.

A few years later the Cowles Company

acquired the Bradley patent, which claimed control of a process of passing a current through an ore of aluminum so that it was melted and decomposed. The Cowles Company in 1900 brought suit against the Pittsburgh Reduction Company, lost, appealed and won a seeming victory in 1903, yet with the final result practically a draw.

Patent struggles beset Hall, for in France young Heroult was granted a French patent for the same independent discovery just two months after Hall's discovery in Oberlin and applied for a United States patent.

Hall filed his fundamental patent No. 400,766, on July 9, 1886, but, thanks to Professor Jewett and others, he was able to prove the February 23 date of discovery and was granted his patents on April 2, 1889.

Upon the occasion of awarding to Hall the Perkin Medal in 1911 Dr. Charles F. Chandler, of Columbia, said, "Dr. Hall's achievement certainly entitles him to a place in the front rank of electrochemists."

Dr. J. W. Richards, of Lehigh, added, "I regard the bringing of aluminum into the ranks of the cheaper metals as one of the great metallurgical achievements of the nineteenth century."

Yet when the first American aluminum was made it was locked up in the safe with the sad reflection that nobody wanted it. To secure markets "Hall and his associates had to learn how to cast and to roll aluminum, to forge, draw and stamp it, because no one else cared to learn how, and yet until those methods were learned and perfected, aluminum could not readily be utilized."

Credit must be given this group, now the Aluminum Company of America, for their enterprise, technical skill and success in discovering new uses for the metal and its alloys.

The greatest modern development is really in the field of light alloys, which make possible metal airplanes, light trains, aluminum hopper cars, trucks, truck-tanks, auto pistons, weight-saving passenger busses and its extensive architectural use.

The commercial metal finds its use in the 425,000 miles of aluminum power cable, a million or more cooking utensils, paints and foil that insulate from heat and cold for houses, oil tanks, milk trucks and the heads of British soldiers in the African deserts. Admiral Byrd found the foil convenient in keeping in the heat (reflecting it back) of his Antarctic hut. Now a football player trades a badly cracked rib for a new one of aluminum. Strange uses are legion.

Cleverness in depositing a hard film of oxide on the metal by electrolytic oxidation has opened up new fields. To mention one only, dry point etchings are now made on such hardened plates.

Charles Martin Hall was a genius, a dreamer, a lover of music and art, a philanthropist—and a good business man. When he died in 1914 he willed one third of his estate to his alma mater, Oberlin College, a gift that can now be estimated as worth approximately $15,000,000.

It is appropriate that Oberlin should have celebrated the Half Century of Commercial Aluminum on February 23. Appropriate, too, that the principal speaker should have been Professor Colin G. Fink, of Columbia, who gave the world chromium plating and now gives it effective and useful aluminum plating of steel and other metals.

THE AGE OF THE EARTH FROM SEDIMENTATION

By Professor GEORGE D. LOUDERBACK
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After the recognition that the sedimentary rocks of the crust are really ancient marine or continental sediments, and that the contained fossils are actually the remains of formerly living organisms, the gradual development of a geological history of the earth became possible. Those who studied these ancient deposits became more and more impressed with the amount of time involved in the vast accumulation of sediments and the great changes in life forms compared with the slight accumulations and changes that have been recorded in human historic time.

Systematic study of geologic history has been in progress only for the last two or three centuries, and during the greater part of that period the students of this science worked under inhibitions and limitations imposed from without, which seriously delayed satisfactory interpretations and definitely modified the conclusions as to the time involved.

The first major limitation arose from the teachings of the church. It was particularly potent because it was a part of each worker's fundamental concepts or philosophical background, instilled into his mind in his childhood and intertwined with his religious views. It prescribed a time limitation for the total history of the earth, the time since the earth's creation, and any proposal to extend this beyond the allotted time was resisted by public opinion (including the opinion of the educated and influential), and the proponent was subject to a charge of heresy.

Viewed purely as a physical geological matter, the question was a problem as to the amount of time required for a given series of events to transpire. It was not solved at the time by setting a definite figure, or even a rough quantitative estimate within wide limits. The limitation imposed by current theological arguments, of approximately 6,000 years since the creation of the earth, was so ridiculously inadequate, that once a realization came of the actuality and nature of the remarkable series of developments and changes which have taken place in prehistoric, in prehuman time (and Adam, the first human of the then orthodox account, you remember, was said to have been created only a few days after the creation of the earth itself), no actual numerical estimate was necessary. Nor was it possible in those days.

As the minds of students of "earth" history were gradually freed from this limitation of orthodox cosmogony, there followed a period during which the more open-minded worked under the impression that there was practically limitless time at their disposal. This period may be considered as beginning with Hutton in the latter part of the eighteenth century and flourishing in the first half of the nineteenth century. Most geologists during that period were busy with reconstructing the succession of events of the past without attempting any estimate of the time involved. A noteworthy exception to this was Lyell, who made an estimate of the time necessary to bring about the change of species during Tertiary time (20 million years) and then, dividing the history since Cambrian time paleontologically into twelve equal parts,

arrived at a total of 240,000,000 years. The basis for his figures was arbitrary and hypothetical.

But soon a new limitation was imposed on geologists. In 1862, Lord Kelvin (then Sir William Thompson) insisted that the practically unlimited time for earth history accepted or demanded by most geologists was opposed to known physical facts. His calculations were based on the internal heat and rate of cooling of the earth, on tidal retardation and on the origin and age of the sun's heat. The first of these methods he considered to rest on the most trustworthy quantitative data. He at first placed the extreme limits for the external consolidation of the globe between 20,000,000 and 400,000,000 years ago, but, in the course of later considerations, he favored more and more the lower limit, his final statements toward the end of the century insisting that it was "more than 20, and less than 40 million years, and probably much nearer 20 than 40" (1897).

This was a great blow to the comparatively recently acquired freedom under which geological thought had been developing, and it came from an unexpected source, and one hard to combat. With much misgiving, geologists were attempting to adjust their concepts of geologic time to this physical limitation when they were placed under still further restriction by another physicist, Professor Tait, who held that the time that could be allowed geologists was somewhat less than 10,000,000 years. This was met by the almost unanimous objection on the part of geologists as being palpably insufficient on the basis of the roughest kind of geological yardstick. While they were not in a position to break down the physical argument, they felt certain it could not be valid. The whole situation created a demand for a quantitative basis for geological and paleontological development, a need not felt in the preceding century.

Ideas of the amount of time involved in geological history have been acquired by geologists chiefly through the study of sedimentary rocks and their contained fossils. Calculations of time based on the thickness of sedimentary accumulations in the main go back not to direct measurements of the rates at which specific sediments are deposited, but to measurements of rates of transportation of material going to make up sedimentary deposits of the present time, and of the areas from which they are being removed. This gives the rate of denudation, and deposition is the complement of denudation. It is sometimes referred to as the hour-glass method of determining geological time.

The usual practice has been to use either mechanical sediments alone, or the total sediments; but some calculations have been based on the removal of calcium and corresponding deposition of limestone, others on the removal of sodium chloride and the accumulation of salt in the ocean.

It is interesting to note that the first suggestion connecting time and deposition was apparently made by the Greek historian Herodotus, who estimated, in the fifth century B. C., that if the Nile were diverted into the Arabian Gulf, it would fill it up with sediment in 20,000 years. In recent time, Phillips seems to have been the first to use the method for estimating the age of the earth, his resulting figure being 96,000,000 years (1860).

Within the last 75 years a number of geologists have made time calculations on the basis of rates of denudation and corresponding sedimentation. While such calculations are based on a simple principle, as in the case of the hour glass, the solution of the problem is fraught with difficulties, uncertainties and arbitrary assumptions. Naturally, therefore, different geologists came to different results, and it would be of no value in this discussion to take them up individually.

But before discussing the method further, I would like to emphasize certain general aspects and results.

The most important result, in my opinion, was that geologists, with but a few exceptions, became agreed that they could not be bound by such low time estimates of physicists as those of Tait or the later figures of Lord Kelvin. This freed geological research during a fruitful period from a restraint similar, if less restrictive, to the older blight from which it had suffered during the preceding century. On the other hand, I feel certain, after studying the various results, that during the first half century after Lord Kelvin's first pronouncement, most of the geologists who made calculations of the time involved in geological history were consciously or unconsciously influenced by the arguments of the physicists to resolve all uncertain points in favor of those giving results requiring lesser time, and to neglect the serious investigation of the effects of certain conditions that, if effective, would probably add to the time total.

The whole situation changed when the implications of the radioactivity of certain minerals was realized. First, the time-restricting structure built upon considerations of a simply cooling earth crumbled. Then geologists were soon told that they had 2 or 3 thousand million years for their earth history. More than that, this large figure was not permissive, it was mandatory. Geologists must take it whether they think they need it or not.

Since this significant change in physical thought has taken place, substituting for an impressed compressive force on the minds of geologists a marked expansive influence of almost explosive violence, a few papers have been published on estimating the age of the earth on the basis of sediments. The writers have accepted at least as probable approximations the results based on radioactive minerals and have therefore attempted to expand the sedimentation figures to fit the radioactive frame.

Barrell in 1917, in an attempt to clarify the cause of the differences between the earlier sedimentation figures and the newer mineral ones, gave a carefully thought-out statement of controlling conditions in sedimentation and factors in the sedimentary record that would add materially to the time required and that were not taken into consideration by the earlier computers. In a recent volume (1931) on the age of the earth published by the National Research Council, Schuchert, under the title, "Age of the Earth on the Basis of Sediments," does not appear in reality to use an independent sedimentation method to determine the age, but by various devices expands the figures from sediments to fit the results from radioactivity and from this determines the average rates of deposition for the different geological periods.

It is a simple conception that if you measure the thickness of a mass of sediments and know the average rate at which it was deposited, you can calculate the time taken for its deposition. Geologists have been able to measure the thickness of many series of sediments with a greater or less degree of accuracy, but the determination of the rate of deposition is a difficult matter. The first figures that appeared to be of more than narrowly local applicability were based on the extensive engineering studies of the Mississippi River. They gave the average value for sediment derived from the denudation of a large area (1,147,000 square miles) including high mountain, intermediate and lowland country under a variety of local climatic conditions. It was believed, therefore, to be a representative figure, expressed in terms of denudation of 1 foot in 4,500 years.

While this figure for the Mississippi drainage area has been favored as a gen-

erally usable rate by many for the reasons just given, it should be noted that other river systems give different rates. The Danube, for example, gives a slower rate, while the Rhone, the Upper Ganges and the Po give faster rates. The rate of the Danube is about 14 per cent. slower than the Mississippi, and the Po about 8 times as fast. The drainage areas of these other streams are all considerably smaller than the Mississippi, that of the Po being only about 30,000 square miles. Some geologists have used an average rate for the different rivers.

To get from the above figures the average rate of deposition, one must estimate the area within which the deposition takes place. For example, the land yielding sediment to the Gulf of Mexico has been estimated at 1,800,000 square miles, while the area of the gulf is only about one tenth of that. The average sedimentation rate in the gulf may then be taken as approximately 10 times the denudation rate or about one foot in 450 years. To get an average value for a whole continent, or for the world as a whole, as some have attempted, requires a series of supplementary considerations and modifications which become more and more uncertain, but which I will not take the time to discuss.

While the earlier calculators of geologic time on the sedimentation basis used a variety of rates, many of which were rather uncritically and arbitrarily chosen, they all agreed in one practice; that is, of basing their particular rates on present-day conditions and action, and applying them uniformly throughout the geologic record. That is, a thousand feet of shale deposited in the Cambrian period was taken to indicate the same number of years as a thousand feet of mud deposited at the present time. This extreme uniformitarian attitude was persisted in even after the development of another branch of geology had distinctly shown that the rate of denudation must vary markedly at different times.

If, for example, we take the average height of North America as 2,132 feet and, for simplicity's sake, apply the rate of denudation of the Mississippi drainage area to it as a constant rate, the whole continent would be reduced to sea-level in about 9,500,000 years. But it is quite evident that as the general elevation is lowered the rate of denudation must decrease and, long before the whole continent is reduced to sea-level, would become extremely slow. Geologic history shows that in a number of periods the lands tributary to a basin of deposition reached a late stage in the erosion cycle, as it is called, and the rate of deposition must have been but a small fraction of the rate calculated from present observations. Rates of denudation determined from any of the great river systems of the present day owe their rapidity to noteworthy wide-spread conditions of continental uplift, combined with great mountain and high plateau building activities of the geologically recent past. While other periods of continental uplift and mountain building have occurred in the history of the earth, there have been intervening long periods of prevailing low-lying lands and slow sedimentation.

The results of the use of present-day rates as uniform rates throughout geologic history had the effect of greatly reducing the calculated age of the earth below its true value, but had the psychological advantage of bringing it within at least the more liberal limitation imposed by the physicists of the time.

The first attempt to develop quantitative values for different specific rates for particular geologic periods on the basis of physiographic control and the relative sizes of denudational and depositional areas for the period under consideration was made as recently as 1926 by H. P. Woodward (quoted in National Research Council Bulletin number 80, pp. 51–54). He postulated that "the curves of denudation values for the pluvio-fluviatile cycle must take on a form

resembling the profile of equilibrium of a stream.'' He analyzed the present relief of North America into percentage of high, moderate, medium and low, with an estimated rate of denudation for each. Then for different divisions of geologic history he computed from paleogeographic data the area submerged and the prevailing relief distribution of emergent lands. On this basis he developed appropriate rates and applied them to the strata deposited in the selected divisions, giving himself a leeway expressed by minimum, mean and maximum values. The results for the time from Cambrian to Recent approximate those derived from radioactivity, probably more so than would have been the case if their author had not known of the results of the latter calculations. The data on which they are based can not claim a high degree of accuracy, but the improvement over the older type of calculation is very great and warrants the belief that the results are much nearer the truth.

To indicate the quantitative effects on the result as compared with the older use of the present-day rate as a uniform rate, I will give some of his figures. The rates here given are means of those developed by three different methods of calculation.

Present	1 foot in 860 years.
Tertiary	1 foot in 1,206 years.
Mesozoic	1 foot in 1,384 years.
Neopaleozoic	1 foot in 1,646 years.
Eopaleozoic	1 foot in 2,483 years.

His figures give a mean value of time since the beginning of the Cambrian of 686.5 million years; minimum 550.4, maximum 822.6.

Besides the previously mentioned difficulties, there are others inherent in the sedimentation method.

A basin of deposition is not of uniform depth throughout, and the resulting series of sediments is thickest along some belt and thins out towards the edges. In studying the older formations, the geologist can usually not measure the areal extent and thickness throughout and so determine the total volume of sediments, recalculating to an average thickness. The usual method of handling this problem has been to consider the whole body of sediment as essentially a prism, the maximum thickness being measured and considered approximately twice the mean.

Another troublesome problem is that of discontinuities. Series of sediments rarely show evidence of continuous sedimentation. Many small breaks known as diastems may occur, representing cessation of deposition for a longer or shorter time. Most of these may cause no difficulty, as they are probably essentially allowed for in the average rate. But at intervals evidence is found, not of mere cessation of deposition, but of active erosion and removal of formerly deposited sediments. Such breaks may be disconformities or unconformities. In a large basin of deposition, lasting over long periods of time, earth movements may change the location of the shore line, and the relative position of sea level, giving rise to disconformities or, if distortion of the crust is involved, even to unconformities. Such breaks may affect only the border areas of the general basin, and sedimentation may be continuous in the more central areas. This is one of the reasons why it has been the practice in measuring strata for time determinations to use only the maximum thickness of sedimentary groups. They are more likely to represent the more continuous seat of deposition, and any less thick portions can not be so well estimated with respect to the mean or any other definite rate.

But at certain times in the earth's history great areas of former sediments have been subject to erosion, and the material has been carried to parts unknown, possibly under the present oceanic areas. The resultant gap in the record is difficult to allow for in time,

although the intervening marked changes in life forms impress geologists with the idea that a long time is represented. Occasionally an attempt has been made to bridge an unconformity by estimating the amount of change that has taken place in the organisms on the assumption that such changes progress at a uniform rate. But others believe that the earth changes or "revolutions" that produce, among other things, the major unconformities, have an accelerating effect on organic changes. An independent time clock, such as radioactivity may ultimately produce for us, is the only hope I can see of solving this highly interesting problem of organic evolution. At present we must consider time assignments to certain unconformities and disconformities as rather uncertain guesswork.

Another difficulty of time calculations is due to the fact that measured series of sediments do not have the character of uniform rock detritus, but are commonly differentiated into sandstones, shales and limestones. These different types of sediment normally form at different rates. If the total amount of all these sediments were known for a certain series, or if their relative proportions in a measured section corresponded to the proportions of their constituents in the source terrane, no special attention would have to be given the separate types, as the average denudation rate would cover the whole. But in actual measured sections, certain types frequently are in undue proportion as a result of lateral segregation of material; that is, different types are selectively deposited in different areas of the basin. So different rates have to be adopted for the different types. This introduces factors of dubious validity into the calculations. Undoubtedly the rate ratios are not constants under all conditions, and the use of fixed ratios in all sections of geologic history introduces errors the probable value of which it is not possible to estimate at present.

I have tried to show that with all the shortcomings and imperfections of the earlier use of the sedimentation method of estimating geologic time, it served a most important scientific purpose in the latter part of the nineteenth century. A critical examination of its basis and a first attempt to bring it in line with other developments in geology indicate that it is capable of yielding greatly improved results and of aiding a more reasonable understanding of the events of geological history. I have presented no figures of my own of the age of the earth based on a study of sediments, because I do not believe that at the present time such figures would have more than a qualitative value. From that standpoint the most important fact is that the best revised approximation of the time calculated for the more definitely decipherable part of geologic history—from the Cambrian to the present—gives values of the same order of magnitude as the methods based on radioactivity. In other words, at the present stage of development there is no recognized conflict between the results of the two methods. I hope there never will be. Geology needs an independent time clock that runs at a uniform rate, just as we need it in our daily life, and the physicist needs it in his laboratory.

The geologist has an immense number and a great complexity of conditions, processes and events to interpret throughout long stretches of time. For this purpose the ideal would be to have independent time markers at frequent intervals in earth history, so that the variable rates of deposition could be determined accurately for the different periods. In this way geological research would be greatly aided in the interpretation of conditions—geographical, climatic, biologic—that obtained during such periods. Furthermore, proper time allowance could then be made for discontinuities in the geologic record which now must be handled by guesswork.

It is evident that the sedimentation method suffers primarily from variable rates that are difficult to establish, and from discontinuities which it offers no good means of estimating. It is much more suited, in general, for determining extreme minimum values than actual values.

So far I have made no specific mention of Pre-Cambrian time. Its estimation by sedimentation method encounters all the difficulties outlined above and others of a formidable character. The chief of these is the lack of satisfactory means of correlation. To explain, it may be pointed out that in no continuous section on the earth do we find all periods of earth history represented by maximum values of sediments: usually a number of periods are not represented at all. In dealing with time from the Cambrian to the present we may correlate disconnected sections in different parts of a continent or even of the world by means of fossils. Thus we may find the maximum development and best measurable section of one period in Pennsylvania, and of another period in California, and piece them together from all parts of the continent to calculate the total time involved. But the Pre-Cambrian rocks carry few or no fossils, and we can not well piece the various sections together and be sure we have the whole history arranged in proper sequence. Furthermore, discontinuities are most strikingly developed, and one is at a loss to make an estimate, even roughly, of time involved. The minimum value given by sedimentation under present knowledge is therefore likely to be in much greater measure below the actuality than it is in later geologic history. In this vast stretch of earth history, a satisfactory radioactive time clock would be of especial value, for it would not only give time, but give us also a greatly needed means of correlation of different sections.

Before leaving the sedimentation method entirely, I must mention a comparatively recent development that gives surprisingly accurate time values: the study of varve sediments. By this method time involved in certain sediments can be determined by counting individual years, with results of a high degree of accuracy if good comparative sections can be obtained. Unfortunately, this method can be used only for small fractions of the geologic record. It was first proposed by De Geer (1910) in connection with glacial sediments. The contrast between the frozen winter and the active summer discharge of detritus gives rise to marked seasonal layering in the deposits and allows their recognition even in ancient sediments. A similar method has been applied to certain other sediments believed to show seasonal banding, but it is yet questionable how far this method can be carried. In deltas or other river sediments the laminations may allow the counting of floods, but, depending on conditions, floods may occur oftener than once a year, or, in certain arid streams, once in several years, and the time element becomes more uncertain.

In conclusion, time estimates from sedimentation are only accurate in certain small fractions of the geologic record, give fair approximations for other parts, but are not suited, unaided, to give a satisfactory figure for the total age of the earth. But the relation of sedimentation to time is a very valuable conception that is bound to be of constant importance in geological interpretation. Even now, if we accept all the results of radioactivity, we must use the sedimentation method; for the points on the radioactive time scale are very few, and the lengths of time to be assigned to specific periods must still be determined by the ratios and rates developed from studies of the sediments, and it may be necessary to use them for this purpose indefinitely.

SOIL POPULATIONS

By Dr. ARTHUR PAUL JACOT

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ANTS and rodents are usually thought of as constituting the population of the soil, as well as earthworms and some insects. The élite of pedology also recognize the hosts of bacteria and protozoa found throughout organic soils. One may be vaguely conscious that some insects get into the soil for reasons of their own. But this assortment of odds and ends of the animal kingdom are local in their effects as compared to that of the minute segmented-animals (arthropods) so numerous and generally distributed in organic soils as to be of outstanding importance in making and keeping the soil full of minute channels which make it possible for rainwater to enter it instead of running off the surface. The intricate, ramifying patterns which these microarthropods establish are of far greater importance in water percolation than mechanical soil porosity—as evidenced in soil which has been so eroded as to have lost this *animate layer*. Not only do these animals extensively channel the soil, but they greatly increase its fertility when not interfered with by man. To follow the course of events let us begin with a moribund tree.

As the tree dies, molds and mildews develop in its inert parts, gradually softening them up. This is just as true of the extensive underground system of roots as it is of the familiar ramifying crown. As the roots are softened by the fungi the host of minute segmented animals find their way in through cracks in the root bark and through the ends of rootlets which died some years earlier. In fact, the root system of a tree, like its crown, is in a continual state of change, old rootlets dying and new ones being formed. This occurs through all the years, once a tree has attained a fair size and degree of growth. Such changes in the root system are due, among other factors, to very local and slight changes in water content of the soil. No sooner are the unused rootlets softened by fungal decay than the minute arthropods which live in the soil and have passageways along the roots and rootlets eat up the decayed wood and thus hollow out the rootlets. These excavations are carried on by generation after generation of the saprophytic arthropods, extensive family-trees being developed within the root of a single large tree. As the root-bark is much more resistant to decomposition it remains as a cylindrical wall about the tunnel, with holes here and there where root branches originated. As may be judged, the process of the eating out of the roots is carried on from different directions, so that, at times, the tunnels thus formed meet. Long after the entire tree is dead the work goes on until the hold of the tree on the soil is so weakened that it comes crashing to the ground, leaving a large depression where the butt once stood. The rain water accumulating in the depression drains through the partly excavated roots and is distributed through the surrounding soil, thus changing the water relations and water supply of the neighboring plants.

As most of the saprophytic (dead wood eating) microarthropods are less than a millimeter (a twenty-fifth of an inch) in breadth any one of them would be lost in a root two or three inches in diameter. Yet some of them are so much smaller (one-tenth millimeter broad) that they can eat out the small rootlets, while the immature stages (of which there are four in the saprophytic mites) are very much smaller than the adults.

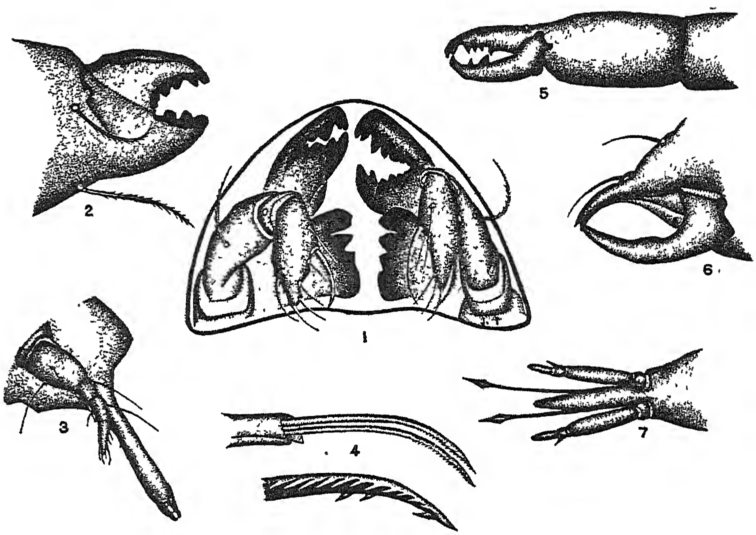
It is in fact the immature animals which do the bulk of the eating. Although soft and white, while their parents are hard and amber-colored to brown, they have very hard, efficient mouth-parts. For instance, the mites have a pair of mandibles which much resemble tinner's snips, a pair of maxillae which resemble heavily nicked chisels, and a pair of finger-like palps, besides a tongue-like ligula. These organs are so mounted in the front of the head that the mite can put the full weight and strength of its eight-legged body behind them. The adults, though provided with the same kind of mouth-parts, spend a good part of their time wandering about in search of mates and of thrusting their eggs in nooks and interstices where the young larva will find shelter and an abundance of food. The food is digested by bacteria and/or protozoa which live in the alimentary tract.

Gradually, as the colony develops, the wood becomes more and more riddled by the minute tunnels and galleries until the entire root becomes sponge-like, except that the channels usually run with the grain. Some of the excavators, on the other hand, are quite devious in their eating. A factor which causes turns or changes in orientation in some species is the molt. As the six-legged larva grows larger and fatter the body wall becomes too tight. The animal becomes lethargic, stops feeding and a new coat forms inside the old, which cracks open, and the animal steps out with an additional pair of legs. It then proceeds to feed where it had left off, though not always in the same direction. This process is repeated four times to reach the state of maturity so that as one traces out the tunnel of any one individual, one may find four cast-off "suits of clothes" as well as a line of feces. It is the row of feces left along the floor of the tunnel that contributes to the fertilizing action of these animals. For, though small, they make up in numbers what they lack in size.

The process of excavation is not carried out by the saprophytic mites only. Several other groups of minute arthropods are engaged in this process. Moreover, the root may not be entirely cleaned out. A central core of very much channeled wood, with very thin partitions still standing between some of the tunnels, may remain in the root.

As such a root system becomes open to water action, sedimentation begins. The feces are washed to the outer reaches of the system—the tips of the rootlets. Mineral and organic particles are introduced from the outside, especially from the hollow caused by the fall of the tree. Moles and other animals may break through a hollow root. External pressures, due to the growing of nearby tree roots, freezing water, burrowing animals and thrusting moles, may cause some of the hollow roots to collapse. Rootlets of other trees or of bushes, extending in the direction of more water, will find their way into the hollow root and develop freely within it, finding free rain-water and concentrated organic matter. Little by little the entire root system of the old forgotten tree becomes filled up. Where once there was a live root, there has succeeded the extensive system of a fungus, then myriads of minute arthropods with their accompanying predators and parasites, a vast underworld of many species, then running water bearing its burden of organic debris, and finally a tortuous black streak through the mineral soil. Such streaks may be observed along road cuts passing through old woodlands, and their contents removed, and examined under the dissecting microscope.

In the meanwhile other trees, bushes and herbaceous plants have grown senile and their roots have been eaten out. Annual plants yearly contribute their quota of dead roots and rootlets to the



MOUTH PARTS OF SOME SOIL MITES

(1) Ensemble of a typical "saprophytic" mite (Oribatidae), as seen from in front (foreshortened mandibles above, maxillae below, with palps at sides). (2) A single crushing mandible, from side, typical of most "saprophytic" mites. (3) Attenuated mandible and palp of Pelops (a suctorial Oribatid), from side. (4) Very much attenuated mandibles of Gustavia (a suctorial Oribatid). (5) Mandible of a predaceous mite (Parasitidae). Compare the pointed cusps with the molariform cusps of the saprophytic type (1). (6) Mandibles of a predaceous mite (Rhagidia). (7) Stylet-shaped piercing mandibles and palps of a predaceous, suctorial mite (Smaris).

wood-decaying fungi and the host of saprophytic animals that live in the litter and in the soil. The process is continuous. The animals eat night and day (where there is no day) and are stopped only by the processes of molting and of freezing. As soon as thawed they continue their feeding. Such animals may be frozen repeatedly through the winter, feeding between the freezes. To them freezing is sleeping.

Soil populated by annual plants, as is characteristic of mull soils, and especially grassland, is so densely interspersed with minute rootlets, at least some of which die each year, that the soil is kept in a constant state of microchanneling, and these channels are rapily filled with organic debris, if nothing else the feces of the excavators. It is for this reason that grassland soil is black and friable, while woodland soil with no herbaceous cover becomes hard and yellow.

In addition to the root excavators, the soil is populated by a group of minute arthropods which burrow about in the soil, filling it with minute channels which have no particular relation to rootlets. The channels wind about in an intricate, seemingly aimless way. Compared to the granular structure of the soil, the channel walls are smooth, resembling those of earthworm burrows, but in this respect only, for worm burrows are much larger and quite direct and vertical. Occasionally they widen out to form galleries or chambers, especially under a pebble or bit of stone, which is usually quite wet on its under face compared to the surrounding soil. Plant roots and mineral grains occasionally enter into the structure of the walls.

It is quite conceivable that this general soil channeling is due to several factors. Roots alone are not responsible, since plowed land abandoned for a

few years, and supporting a very meager weed flora, is so channeled. One of the factors is the ability of some of the mites to dig. Those of the genus Lohmannia are built like a mole and have the anterior legs fitted for digging. Epilohmannia, though less stocky and longer legged, is also a common inhabitant of soil. Other genera, the species of which are found above ground, as well as within, have the tarsi of the first pair of legs armed with a stout, curved spine. Species of Xylobates have two or three stout spines on their anterior tarsi and the body is quite stout and unconstricted. Other soil mites, which probably do no digging but aid in maintaining these passages, are not particularly modified for an under-ground existence. In fact, many of the litter-inhabiting species descend into the soil when the litter gets too dry or to lay their eggs or for other reasons, so that there is a continual migration between the surface litter of organic plant remains and the soil itself.

This is true not only of the mites but of many if not all of the other groups of soil (and litter) animals. Springtails (Collembola), the group of microarthropods ranking next to the saprophytic mites in numbers in the soil and litter, are very active, and continually on the move. Most of the soil species belong to primitive genera and are colorless (white) and eyeless or with reduced eyes. Some of the species are saprophytic and some are carrion eaters. Although not diggers they help in maintaining the soil channels. Yellow-tips (Proturans), the most primitive of insects, having no antennae but rudimentary abdominal legs, are present in most soils in varying numbers. They are probably eaters of decayed plant tissues. Their narrow heads, elongate anterior legs and tapering yellow abdomen, held slightly elevated and continually vibrating, are their distinctive features. Minute millipedes of the order Pauropoda are soil dwellers. The minute centipede *Scutigerella immaculata,* seven millimeters long and milk white, is fairly common. Very much resembling it is Japyx, another primitive insect easily distinguished from Scutigerella by its brown, caudal, nipper-like appendages.

Some of the larger millipedes are also dwellers of the soil under certain favorable conditions. They require considerable moisture. During times of drought the litter species enter the soil to estivate. In fact, woodland soil becomes highly tenanted during the autumn with species of insects which spend their summers in neighboring fields or the upper strata of the forest. The soil offers them shelter and a certain degree of warmth through the winter. Blake found that in the warm temperate zone these winter migrants moved between the soil and the litter during each warm and cold spell. This would keep the woodland soil much more open and channeled through the winter than through the summer.

Of the predaceous groups there are many kinds of mites, some centipedes, Japyx and certain beetles. Ants are much more common than is generally known. As the commonest species are minute and soil-colored they easily escape notice. They and the earthworms have their own shafts and galleries, thus adding considerably to the opening up of the soil, but contributing still more by bringing the mineral soil to the surface and spreading it out over the organic layer of the surface. In this way they are important as mixers, and being ubiquitous, even to the extent of one or two colonies per square yard, they are of considerable importance. The numbers of earthworms have been much underestimated, because the popular conception of earthworms is the large angle worm. There are, however, several small species and some minute forms which

contribute their mite to soil structure, making up in numbers what they lack in size.

Reliable population studies can only be carried on with special collecting methods adapted to the particular group being investigated. The best sampling method for ants is useless for earthworms. Most of the methods that have been used for soil population studies are designed particularly for securing the larger insects and are therefore highly erroneous for the microarthropods, minute ants and earthworms. Using more appropriate methods, I have found one thousand to two thousand microarthropods per square foot of woodland and grassland soil, and a few hundred per square foot of plowed fields abandoned three or four years and grown to tall weeds.

The above considerations have not taken into account that enormous group of inconspicuous and minute threadworms (Nematodes) which clothe the earth and inhabit all the larger organisms. Here again special collecting methods are needed. Many of the species are saprophytic and aid considerably in the reduction of organic matter. Bear-animalcules (Tardigrades), though found in such limited numbers as a dozen or more per square foot, contribute their share in maintaining soil tilth and soil fertility.

It is not the very local effect of such conspicuous animals as the woodchuck or prairie-dog which contributes markedly to soil fertility, soil mixing (plowing) and soil channeling, but the effect of the myriad animals found throughout all organic soil, animals which are not of such microscopically small size as to pass between soil particles, but large enough to establish and maintain innumerable channels many times larger than the interstices of the soil particles and soil granules, that are of cardinal importance to soil management. When these minute animals are removed by intensive erosion they must become reestablished before soil can again become fertile and generously receptive to rainwater.

SCIENCE SERVICE RADIO TALKS

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SOUNDING THE SEVEN SEAS

By Commander J. H. HAWLEY

ASSISTANT DIRECTOR, U. S. COAST AND GEODETIC SURVEY

SEVERAL months ago a small ship was cruising along the Pacific coast of the United States. In the pilot house the officers on watch were paying close attention to a small mysterious-looking black box which seemed to be putting on a miniature display of fireworks.

This craft was a ship of the United States Coast and Geodetic Survey; one of a fleet which is constantly engaged in surveying our coastal waters in order to provide the marine charts required for ship navigation. The black box was the main unit of an echo-sounding instrument—a remarkable device which measures the time required for a sound to reach the bottom of the ocean and return as an echo, computes the distance traveled and then indicates the depth under the ship by flashes of red light on a graduated dial.

Work that day was rather monotonous, for the ocean floor, some 50 miles out from the coast, was flat as a pancake. Suddenly something seemed to go wrong; flashes of red light came from all positions on the dial and it looked as if the instrument was completely out of kilter. This was not the case, however, for subsequent investigation showed that the ship was passing over a massive submarine mountain, previously unknown, which rises over 7,500 feet above the ocean floor.

And thus one more of the ocean's secrets was revealed—secrets which have been disclosed slowly by hazardous exploration and painstaking investigation. This search for knowledge has been carried on almost from the time when primitive man first gazed out across an apparently unlimited expanse of water and, no doubt, speculated on what lay beyond the horizon and what existed beneath the surface of the sea.

As man became more daring and ventured farther and farther from land, information with respect to the extent and location of the oceans was gradually accumulated. Much later, in comparatively modern times in fact, comprehensive knowledge of depths and the configuration of the sea bottom in coastal areas became more and more essential for ship navigation. Finally there was need for information concerning oceanic depths beyond the requirements of navigation, for various branches of scientific research and for such practical purposes as the laying of submarine telegraph cables, location of fishing banks and the like.

At the present time our geographic knowledge of the extent and boundaries of the oceans is practically complete, and most nations have executed surveys as far out from their coasts as is necessary for navigational purposes. Beyond this limit our information concerning the depths and other features of the sea is much less comprehensive. We do know enough, however, to give us some idea of the general conformation of the ocean bottom and of certain characteristics, such as temperature, salinity and marine life, of the waters which cover about 71 per cent. of the surface of the earth.

As might have been expected, one of

the first facts disclosed by early investigations is that the configuration of the ocean bottom does not differ greatly from that of adjoining land areas. And so we find submerged mountains and plateaus rising to form shoals or banks; submarine valleys known as troughs or trenches; ravines in the continental shelf called furrows, and other forms with which we are familiar on land.

At some places the bottom sinks considerably below the general level and forms marked depressions which are designated as "deeps." This term is generally used for areas where the depths exceed 18,000 feet and on this basis there are some 50 known deeps throughout the oceans of the world. Probably the most interesting of these features are the deeps, each of which constitutes the greatest known depth for the particular ocean in which it is located.

The principal deep in the North Atlantic Ocean is the Nares Deep, a short distance north of Puerto Rico, which was discovered in 1902 and has a depth of 27,972 feet, or about five and one third miles. In the South Atlantic Ocean a maximum depth of 26,575 feet was recorded in 1926. The greatest depth found in the Indian Ocean is the Wharton Deep, close to the south coast of Java, where you would have to go down 22,968 feet to reach the bottom. In the Arctic and Antarctic Oceans maximum depths of 17,850 feet and 14,274 feet, respectively, have been measured.

I have left the Pacific Ocean until the last, for in this ocean, close to the Philippine Archipelago, we have the greatest known depth of any of the oceans of the world. In this region a remarkable trench or submarine valley extends over 500 miles along and past the east coast of the island of Mindanao, and in this trench is located the Mindanao Deep, where, as discovered in 1927, the depth is 35,400 feet—over six and one half miles; a depth so great that if Mount Everest in the Himalayas, the highest known mountain in the world, were placed in the Mindanao Deep, its summit would be over a mile below the surface.

The Mindanao Deep is one of several extensive depressions in the western Pacific. Next in rank is the Tuscarora Deep near Japan with a depth over 32,000 feet. The Nero Deep, near the island of Guam, and the Aldrich Deep, a short distance northeast of New Zealand, both have depths of about 31,000 feet.

That the great depths of the oceans are of considerable general interest is indicated by the frequent inquiries which are received concerning them. One popular idea, much in evidence when a marine disaster occurs, is that an object sinking in the ocean eventually will reach water so dense, under the enormous pressures which exist, that it can not be penetrated; the result being that the object, after reaching a certain depth, will there float indefinitely. This thought also has attracted the imagination of writers of prose and poetry on many occasions. For instance, we have these lines by Longfellow:

> Beyond the fall of dews
> Deeper than plummet lies,
> Float ships, with all their crews,
> No more to sink or rise.

It is rather distressing to cast discredit on an idea that can be expressed so beautifully. As a matter of fact, however, water is almost incompressible and any object heavier than the water it displaces will sink and will continue on to the bottom, regardless of the depth.

Apparatus for measuring depths has been gradually developed through the ages, but it is only in comparatively recent times that the greatest depths of the oceans could be plumbed. The mod-

ern equipment for direct measurements is an electric or steam sounding machine having a reel on which several miles of fine piano wire are wound. To the end of this wire is attached a pear-shaped sinker of cast iron weighing from 35 to 75 pounds.

The wire in its downward fall passes over a sheave of known circumference which registers the length of wire run out in about the same fashion as the speedometer of your automobile. When the bottom is reached, the cast-iron sinker is automatically detached and abandoned, so that the wire can be reeled in with less danger of breaking.

Nothing is more impressive of the great depths of the ocean than to watch, second after second, minute after minute, for a half hour or more, the rapidly revolving drum of a sounding machine from which the wire unwinds. Finally the bottom is reached and there comes to the observer a sudden realization of his elevation of several miles above the bottom of the sea. It would require over two hours to sound the Mindanao Deep with a sounding machine—about one hour for the weight to fall and an equal time to reel in the wire. Advantage is taken of wire soundings to obtain specimens of bottom material and to secure water samples and measure temperatures at any depths desired, various instruments being available for these purposes.

Temperatures of sea water from the surface down to the bottom have been obtained at many points in the various oceans. As would be expected there is great variation in the surface water temperatures in different latitudes, and these temperatures decrease more or less rapidly with increase in depth. Regardless of the latitude, however, at a depth of about one mile, the temperature drops to a little above the freezing point of fresh water and then remains practically constant all the way to the bottom, whatever the depth may be.

Valuable as they were, the gradual improvements in sounding machines and accessories have been overshadowed in recent years by the development of echo-sounding instruments which I have mentioned. Sound travels through the water at a speed of about 4,800 feet per second so that a sounding which formerly required an hour or more can now be obtained in a few seconds, and this without stopping the ship which, of course, was necessary with the older methods.

In depths up to about 600 feet a ship, running at full speed, can now obtain four soundings every second; while in depths from 9 to 120 feet a new instrument, recently developed by the Coast and Geodetic Survey, measures depths at the almost incredible rate of 20 soundings per second.

Much work has been done in oceanic research, but the field is so vast that we have made scarcely more than a beginning. With the development of echo-sounding instruments and their increasing use, not only on survey ships but also for navigational purposes on vessels of the Navy, Coast Guard and merchant marine, it is apparent that a new era is dawning in this study. I am confident that our knowledge of the seas, at least with respect to the configuration of the ocean bottom, will increase much more rapidly from now on.

In a short talk of this nature it is possible to cover but a few phases of a topic so extensive as oceanography and only to touch on the high spots of the branches selected, although I seem to have devoted my time mostly to the low spots. In so doing I hope that I have been able to tell you something of interest. I am sure we can all agree on one thing at least, which is that the subject certainly is not a dry one.

THE LURE OF ARCHEOLOGY

By N. C. NELSON

CURATOR OF PREHISTORIC ARCHEOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY

ARCHEOLOGY, or the study of relics pertaining to man and to his mode of life in times before history came to be written, has been a topic of considerable interest to this country for about 150 years. It began to attract attention immediately after the Revolutionary War, when many of the discharged soldiers moved out into the Ohio Territory to take up land and there discovered numerous great mounds and other earthworks, which they erroneously attributed, not to the Indians, but to a mysteriously vanished people whom they called the mound-builders. For about a century thereafter, or throughout our busy pioneer period, actual antiquarian pursuits, as far as we know, were limited to a comparatively few individuals, either of a scholarly turn of mind or endowed with the instinct for collecting. Among these early amateurs, it may interest you to know, were at least two Presidents of the United States, one of them being Thomas Jefferson. But during the last fifty years trained investigators have come forward, and one of the results of their intensified and improved work is that to-day widespread popular interest, not only in American antiquities but in the archeological findings of the entire world, has become generally apparent and is steadily growing. It is my purpose on this occasion merely to suggest to you some probable explanations of this phenomenal enthusiasm for knowledge about prehistoric man.

If by chance you are not personally fascinated by the collection and study of Indian relics, or if you are not directly aware of the public response to these activities, allow me to call your attention to a few proofs. First, there is the daily press, which in recent decades has furnished an ever-increasing amount of news about archeological discoveries in all parts of the world. The opening, for instance, of Tutankamen's tomb in Egypt in 1922, and the later removal of its contents, were considered "good copy" off and on for a period of years. And when last spring a mummified body was found in Mammoth Cave, Kentucky, the details were circulated through our newspapers from coast to coast and doubtless reached even the foreign press. Then there is the lively interest shown of late by the Boy Scouts and similar organizations in hunting and digging for arrow-points and such things all over the country. Many individuals, within and without these groups, are making private collections of more or less value and far more stimulating, as I believe, for independent thinking about human affairs than, for example, the collecting of postage stamps can ever be. Incidentally, I may tell you that scarcely a week passes that I do not personally receive a letter from some young man or woman—even occasionally from grammar school children—who wants to know how to become an archeologist. Finally, in our larger cities, like New York and Chicago, the museums are visited annually by hundreds of thousands of school children, and they are giving special attention to the archeological exhibits. In the meantime, several of our universities have acquired small collections for teaching purposes, and the day is probably not far distant when even our secondary schools will have displays of Indian relics of local origin to serve as a supplement to

the teaching of American history. Why, we may well ask, this all-round genuine interest in prehistoric archeology?

A precise and positive answer can not of course be given in fifteen minutes. Indeed, there are doubtless many answers, and by exploring our subject, even if hurriedly, from center to circumference, as it were, we shall certainly discover some of them.

Our most natural starting point is at the circumference or vague outer limits of the field. Here, then, we may properly begin by asking whether the reason for the present popularity of archeology may not be connected with the general truth that we are all, without perhaps clearly knowing why, deeply interested in everything that directly concerns human kind. Most of us, in our idle moments, are talking about ourselves and our acquaintances, *i.e.*, about man, and only rarely about things. The ancient Greeks actually had a motto which read "Know thyself" and which indicates what they considered the most important subject for study. Pope, one of the English poets, suggested the same idea when he wrote that "The proper study of mankind is man." In short, it appears that there is no escape from the conclusion that in man—in ourselves—are centered finally all our instinctive and rational interests. Why otherwise are fiction and biography so popular, unless it is because we never tire of reading about human behavior? Even the comparatively dry facts of ordinary history have a wide appeal, and when it is realized that archeology is after all only a supplement to history, perhaps we have the basic answer to our question.

But for present purposes we require a more immediate and concrete explanation. What precisely is, then, the lure of archeology or how in specific terms account for its broad appeal? To come to the point at once, may not our common, though perhaps often unacknowledged, love of romance be part of the secret? What youth, for example, has not at some time or other wanted to be a pirate or a treasure-seeker, a prospector for gold, a big game hunter, an explorer or even a merely ordinary traveler? Now it so happens that archeology satisfies in a unique way these longings for adventure. The search for archeological treasure, entered upon by digging in a cave or by walking open-eyed across a plowed field, takes one instantly out of the normal daily routine into direct contact with men and things of an earlier, unrecorded time, and thus gives present life a new and broader significance.

Coming to closer quarters with the subject, perhaps I can do no better than to begin by confessing why I myself became interested in archeology, interested sufficiently to make a lifework of it. It happened this way. As a student in high school I suddenly found it necessary to know something about how, when and where man really originated and, in general, how things as they are in the world to-day came to be so. My history books did not tell me. My teachers either could not or would not enlighten me. As a last resort, therefore, I had to turn to prehistoric archeology. You may easily guess that I have not yet found the final answers to all my questions; but I trust you will believe me when I say that I feel sure we are well on the way to solve these perplexing riddles.

When it comes, now, to other people's interest—your interest—in archeology, I suspect there are many different replies. For an opening I venture to guess that some of you are collecting Indian relics simply for the pure joy of collecting. This collecting habit is a trait which we share with some of the birds and mammals and consequently need not apologize

for or even try to explain. It is enough that its legitimate exercise gives us satisfaction. But no intelligent collector is likely to go very far with his hobby of gathering primitive implements without being impelled to think about the various uses to which they were put and perchance also about what relation they bear to our similar modern implements. Sooner or later, therefore, he will be picturing to himself the kind of life the ancient makers lived; and, if he possesses a complete series of chronologically arranged specimens, he will be perceiving also how by slow stages of improvement the simple early inventions of stone, bone, wood and shell gave rise to our present metallic contrivances. This visible demonstration of origin by gradual modification of most of our own material equipment for life is perhaps the greatest lesson in evolution that archeology has to teach.

We must conclude by citing yet another possible reason for current popular interest in our branch of study. Archeology, while by courtesy called a science, is not quite in the same class with such exact or highly technical inquiries, as, for example, physics and chemistry. In other words, archeology is a study which can, within certain limits, be profitably pursued by any one with ordinary common sense. Special training for effective work is to-day provided by several of our universities; but there are still a number of workers in the field who, without such professional equipment, have for years been making important contributions to anthropological science. It may well be, therefore, that archeology or prehistory is popular in part for the simple reason that it is a study of everyday things—a study, namely, of earthworks, cemeteries, village sites, house ruins, household furnishings, tools, weapons, bodily ornaments, etc.—in brief, a study of things that we all know something about and therefore can to some extent understand. If in addition to this the amateur is aware of the scientific requirements of his task, and knows that by partaking in this world-wide investigation he is really adding new facts to our stock of knowledge about the development of human civilization, he is bound to enjoy a measure of satisfaction such as every discoverer knows.

IN QUEST OF GORILLAS

V. ELUSIVE GIANTS OF THE MOUNTAINS

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

The mountain forest in which the Kivu gorillas roamed and made their one-night camps presented a riotous confusion of new growths. Most of the primal forest had been removed, but there was still a residue of the Old Guard here and there, an enormous tree whose trunk and main limbs were contorted beneath the tightening coils of heavy lianas and vines, while besieging forces had eaten into its very core; but it still reared its head far above the surrounding bush, and its buttresses had defied the assaults of many storms. Here among these grand trees the shaggy black giant apes found a magnificent setting. They too doubtless appreciated the big trees as affording comfortable and dry beds in the tangled branches or at the foot of the buttressed trunks. But to our eyes even the trees of second growth were strange and beautiful, while the thick underbush included an immense variety of bushes and bright flowers, all of which were probably skilfully classified by the gorillas into edible and worthless classes.

As one went further into the forest, up the long curved mountain ridge that surrounded our camp on the west and north, one discovered on his right a curving valley, hereafter called the "Valley of the Elephants," which was mostly screened from view by the high bush. This was traversed by a meandering trail made by wood-cutters; along this trail one could find many delightful details, a beautifully woven purse-like nest hanging from a branch overhead, a big land snail pursuing his leisurely flowing way along the path, a male hornbill flying along and making the silent forest resound with his brazen cackling and whooping.

The first time I discovered this valley I was amazed at its beauty. Near me were high trees with light willowy curving trunks and joyous sprays of leaves at the top. All around were high straight stalks with broad ovate leaves that caught glints of sunlight. I could look away down the slope to the bottom of the valley and with my glasses search the tangled bush there in hopes of seeing something stir. Tensely I waited for a hairy black arm to shake the bushes or a velvet black muzzle to yawn and emit a sharp bark. But nothing stirred and the silence was broken only by the mocking twitter of small birds. Turning my gaze near by, however, I discovered a meandering elephant trail, as the big beast had crashed through the underbrush, leaving dung that was not old in appearance. The next day near the upper end of this valley I found another elephant trail, which showed what very steep mountain slopes elephants can climb.

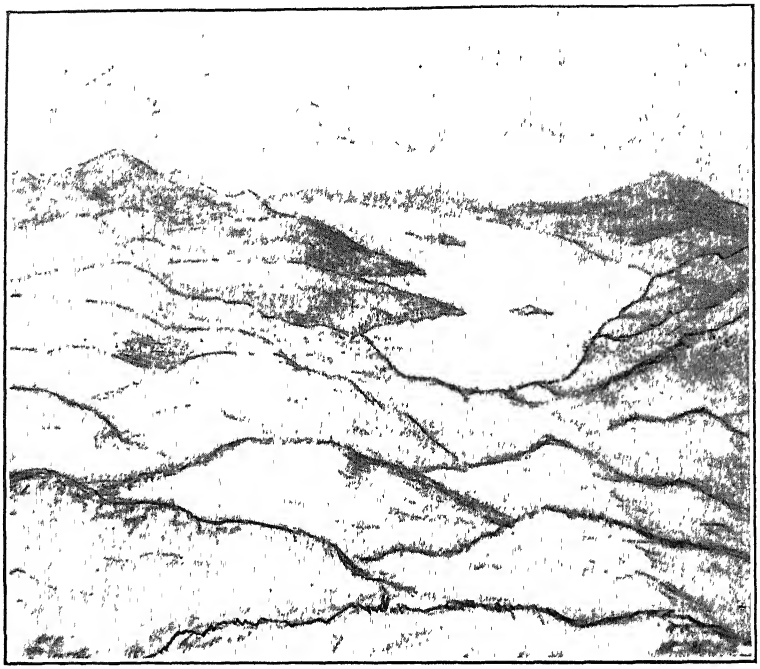
A little way to the northeast of our camp was a place in the forest which afterward became famous to us and which I shall here call *"L'Hotel des Gorilles."* This place was in a general way above and behind a hill which I shall call "Vierstraet's Hill," because it was immediately behind that gentleman's residence. This hill provided me with a training ground in woodcraft, since I frequently got myself lost in its high grass and thick bush and then had an exciting time finding myself again.

But after I purchased the mgoosu from a native I easily hacked my way about in this jungle, leaving a broad trail that not even I could lose on the way back. After several preliminary explorations in this region, one day I took one of the natives with me and made a wide detour around Vierstraet's Hill and the *Hotel des Gorilles*. We passed around a shoulder of our mountain that faced northeast toward the lake and obtained a glorious view of the real Lake Kivu to the north, which was far more extensive than the small southern bay that we faced from our camp. Circling away from the lake view, we entered the forest and came into the "Valley of the Elephants" on the opposite side from that which I had first entered. To our great surprise we found ourselves in a labyrinth of recent elephant paths that were broad lanes through the thick jungle. These paths ran in many directions and were only a few days old. I wondered how the gorillas liked to have a herd of elephants crashing through the forest, but as both gorillas and elephants had vacated the premises my black boy and I retraced our devious way back to camp.

Many a day I wandered in the forest in the neighborhood of our camp, with a mounting desire to spy on the elusive gorillas. The curving "Valley of the Elephants" sloped upward in the direction of the main path up the mountain and finally crossed it, traversing a very deep notch, down which one went far more readily than one ascended the opposite side. Afterward the path wound along, getting higher and higher until one could obtain a fleeting view of the mountains south of Bukavu. Then began the longest and steepest descent of all, compensated by a glorious view of the high and jagged Mt. Kahusi toward the west. The path led through a deep and dark valley, up a steep escarpment on to a plateau of bamboos interspersed with giant trees, where gorilla beds and dung were seen, then down into a big and very wet marsh, through which we four once picked our way in vain pursuit of gorillas ahead. The gorillas finally crossed the marsh and in the late afternoon re-

Photograph by H. C. Raven.

MOUNT KAHUSI.



Sketch from author's note-book

THE REAL LAKE KIVU

tired into the shades of the forest, while we gave up the chase for the day. But sooner or later each one of us saw living gorillas in their native forest

A day or two after setting up our permanent camp at Tschibinda, Raven and McGregor were on the main path leading up toward the ridge when they came near a party of gorillas. They heard several barks, saw the bushes wave and one great black arm appear for a moment, then a black head with a rufous crown; but at this time they were intending only to study the habits of gorillas and there was no opportunity to place the definitive shot through the head to which Raven was restricted by the circumstances mentioned below. The light for photography was very poor, the gorillas were nearly always heavily screened and in our experiences no one was successful in getting either cinema or still photographs. There was room for difference of interpretation as to how many gorillas barked on this occasion, but there seemed to be several. The natives that morning had reported a band of fourteen in the neighborhood, but there was no means of testing their statement. In fact, there seemed to be considerable variability in the number of gorillas in one band, but there was some evidence that some bands included a very large male, at least one other male, several females and young.

My first visual contact with the gorillas was on one occasion when I went with Raven and several Batwas after a band that had been reported by the natives. First we walked up the main path to the top of the first ridge, down the steep valley, then up on the other side Then we left the path and began to crawl through the underbrush, following the erratic trail of the gorilla to right or left, up and down the steep slopes. Climbing over great logs, slipping and sliding on the steep slopes were not so bad, but stooping down to the ground and crawling through small openings in the bush, wriggling on one's stomach, breaking the

entangling vines or trying to untangle one's self from vines and thorns and striving to avoid the nettles, made progress fairly difficult for a middle-aged beginner

After a while there came a loud scream and a scattering of the Batwa. At last, I thought, there is the gorilla! But no, it was only a black bush-pig which had been caught in a snare set by the Batwa the day before. There was further uproar as the pig was quickly speared, then a most ingenious trussing up of the heavy animal until his hind feet crossed his throat and his forefeet were tucked against his sides, after which Nyumba, the most powerful man of the hunters, took the pig on the top of his head and walked nonchalantly away with it down the mountainside.

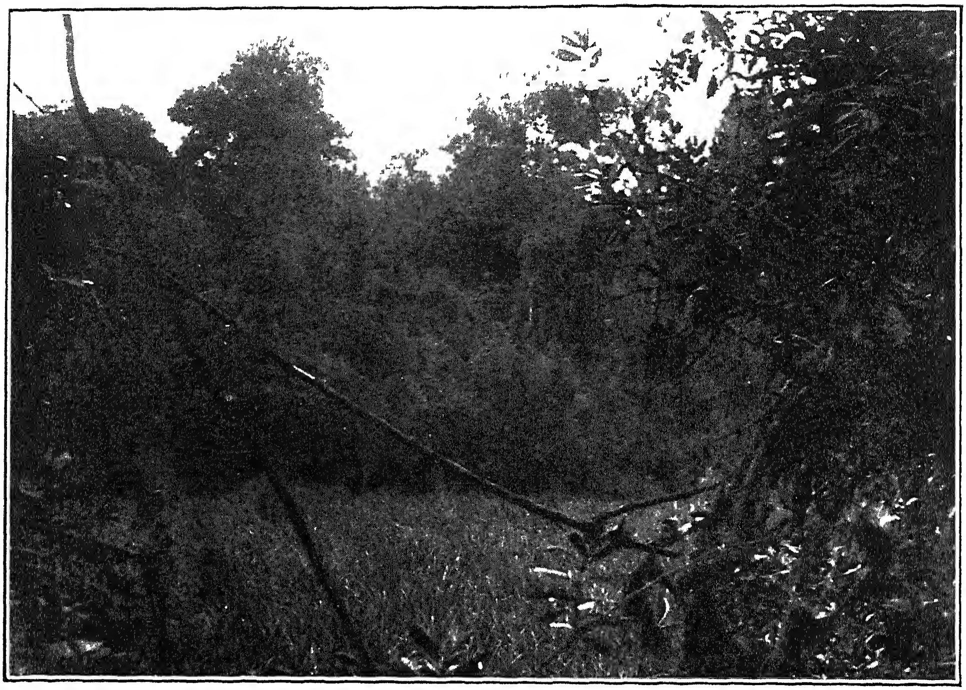
We picked up the gorilla trail again and began a new chapter of "reeling, writhing and wriggling" After a long time there was a loud bark, a sudden waving of bushes and the gorilla disappeared. Raven and several of the Mambutis slithered away like lizards through the bush. When I and my personal attendant Batwa came up with them a council was held. The Batwa told Raven that very few gorillas were left in the neighborhood, that in particular this gorilla was now far on the other side of the steep valley and could not be overtaken as he was thoroughly aroused and could move through the thick underbrush many times faster than a man

Here it is timely to set forth rather fully the special conditions under which our expedition was operating. Most collectors had simply to get near a gorilla, shoot it anywhere in the body one or more times, skin it and take the skin and head back to camp. We had permits to secure two gorillas in east Africa; and we considered that no mistakes or rejects were allowable Our two gorillas must be large adults and they must be shot only in the head If shot through the body, many blood vessels would be cut and it would be very difficult to preserve the huge body evenly, the preservative fluid injected would reach only certain regions; other regions would not be

Photograph by H. C. Raven

SOMETHING TO KEEP AWAY FROM.

NETTLES (*Urticaria*) ON THE GORILLA TRAIL.



Photograph by H. C. Raven

SWAMP NEAR TSCHIBINDA.

ACROSS THIS SWAMP THE GORILLAS RETREATED SWIFTLY, LEAVING US HOPELESSLY OUTDISTANCED IN THE LATE AFTERNOON.

reached by it and would "go bad" perhaps on the ship going home. Moreover, in killing a gorilla one had, if possible, to avoid killing it at some inaccessible locality where it would be difficult or impossible to bring out a four- or five-hundred-pound mass on the backs of porters. Consequently in both east and west Africa Raven had to miss very many opportunities of merely "shooting a gorilla." He could indeed have made a large collection of gorilla skins and skulls in the time it took him to secure our full total of five specimens (two in the Belgian Congo, three in west Africa) under these hampering conditions.

As Raven had already had far more field experience in Africa than the rest of us and was moreover by preference a solitary hunter, operating only with black trackers, he alone did the hunting and shooting of the gorillas; but it was open to the rest of us to take a native or two and go out to find gorillas for ourselves in the hope of securing motion pictures.

Some of Raven's experiences in hunting gorillas in this region have been vividly told by him in an article in *Natural History* (May–June, 1931), from which the following description is quoted:

The present range of the mountain gorilla is in the highlands of the eastern Belgian Congo and the Kivu volcanoes. Our camp in this country was west of the southern end of Lake Kivu, at an altitude of 7,000 feet, on the slope and facing eastward over the cultivated country toward the lake. On a clear day we could see the hazy outline of the mountains on the far side, and on one occasion I could even see the volcanoes north of the lake. The forest began just behind our tents. This was mountain forest with rather low trees interspersed among a mass of succulent vegetation which was from six to fifteen feet high. Many of

the trees on the highest slopes were covered with moss.

As soon as our camp was established I made daily excursions in the forest, accompanied by two or three natives whom I obtained in the neighborhood. We found traces of gorillas, elephants, harnessed antelope, duikers, wild pigs, and buffalo, but we did not get close to any of the gorillas. The natives were not good hunters, and when we came upon signs indicating where gorillas had been feeding or walking, they were unable to say whether these signs were fresh or a few days old. Finally I managed to get some Batwa pygmies, professional hunters, to help me. It was delightful to go into the forest with these little people who understood the forest, whose home it was.

One morning when I had started out with a couple of Bantu natives, two pygmies joined us and told us that gorillas had been feeding in a valley not far away. I accompanied them down the steep slope for nearly half a mile and up another ridge. The pygmies traveled much more quickly than the Bantu hunters I had had, and soon I was tired out. At the end of the steep climb of a half hour I had to sit down and catch my breath. Then we went on, up and down steep slopes, through the thickest kind of tangled vegetation, and finally came upon the trail of some gorillas, which we followed for perhaps a mile. Then we saw vegetation that had been trampled, stalks of wild celery that had been broken off and pulled through the teeth of the animals so that all the green bark and leaves were stripped off and eaten, while the perfectly white inner part, looking like a peeled willow switch, was dropped on the ground. After an examination of these switches, the pygmies turned to me and declared that gorillas were near, that this food had been eaten only a few moments before.

We proceeded very cautiously, one pygmy going before me with a peculiar combination sickle and hatchet (mgoosu), quietly cutting away the vegetation so that we could follow. We had gone along a densely covered ridge for perhaps one hundred yards when we heard a slight movement of the vegetation. On the advice of the natives I took the rifle from the boy behind me and went ahead more cautiously than ever. Suddenly and without the slightest warning there was the most terrific combination of screech and roar, stamping of feet and thrashing of underbrush, as a gorilla rushed at us. The vegetation here except for a few trees was dense as could be, and from ten to fifteen feet high. In order to get through we had been crouching down, often going on our hands and knees. I was crouching when the gorilla began to rush, but in order to raise the rifle in his direction I had to back up against a thick mass of vines and weeds. The gorilla came like a cyclone until he was perhaps thirty or forty feet from us, when he suddenly stopped and was silent.

Photograph by H. C. Raven

PYGMY HUNTERS.

CHILIGONOA STANDS AT THE RIGHT, WHILE NYUMBA IS NEXT TO HIM

The vegetation was so thick we could not see more than ten feet in that particular direction We hesitated a moment, then I motioned the hunter before me to part the vines quietly and go forward I followed, holding the rifle ready to fire. We came to the spot where the gorilla had stopped, but he was not there He had turned about, retraced his steps a short distance, then taken a new course, and disappeared, all without making a sound By this time he was probably some distance away. We followed the trail as quickly as we could, first up along the ridge, then down the side of a steep ravine, until I was dripping with perspiration

As suddenly as before, the gorilla rushed at us and stopped, and precisely as we had done the first time, we followed On the brow of a ridge we came upon a very fine bed where this or another gorilla had slept the night before. It was about three feet in diameter, and was made of bamboo leaves I would have stopped to photograph this had we not been in such hot pursuit.

That gorilla made seven similar rushes before he went down a very steep hill, across a small stream and over another hill nearly one thousand feet high. The pygmies then gave up and turned back, saying: "There is no use following him; he has gone too far."

Another day we had hunted up and down hill for hours without seeing any fresh signs of gorilla, though we saw many old ones At this time I had only pygmies with me, no Bantus Like the fine hunting people they are, the pygmies are ever on the alert to procure any food available in the forest On this particular day, one of them who was ahead scouting called back to us, and when we came up to him, he was standing still, looking up at the trunk of a tree about three feet in diameter. He told us he had seen bees go into a crack in the trunk and that there must be plenty of honey inside.

Well, the hunt was over for that day. The pygmies simply could not think of leaving all that honey there, and promptly went about collecting it. First they cut a sapling about four inches at the base; this they stood against the big tree, and then tied it with vines to the tree at intervals of several feet all the way up. While two or three were doing this, another had found and shredded some bark, which he lighted and waved about, making it smoke profusely. One man climbed to the very top of the sapling, waving the smoking bark, and reached his hand into the crack of the tree. He reported that there was honey there, but said he would have to make the hole larger in order to get his arm in. Another native carried up a little hatchet of his own making. With this he hewed at the crack until it was big enough to admit his arm.

By now, of course, bees were buzzing about his head and all around the tree, sometimes getting tangled in his kinky hair, so that he would have to stop working at the hive momentarily We could see him bring out pieces of comb, the honey would drip down from his precarious perch while he chewed up the comb, spitting out the wax afterward All the natives below were keeping up an incessant jabber, begging him to throw down the honey, but he would only say "Wait," as he licked his fingers and arm

It was not long, however, before he began to pass down pieces of comb to the native who had climbed up just below him Then those on the ground would beg this man, "Pass down some honey," and like the one above, he would reply "Wait!" Finally there were five or six pygmies clinging to the sapling and eating honey. When they had removed all the honey from the tree and we had all had our fill, the remainder was bundled up in leaves and we returned home; for after procuring the honey their enthusiasm for gorillas was gone

Another day we had come upon the trail of a band of gorillas among some bamboos perhaps three miles from camp We followed them for a long way until about 11 00 A M when we came upon the place where they had slept the night before. In an area twenty yards across there were nine beds, all on the ground on the steep hillside. It was easy to see how they had made their nests The gorilla simply sits down among the dense foliage and with his long arms grabs a small sapling, pulls it down, twists it under him, sits on it, and reaches for another. If it breaks off, he takes the piece, arranges it around him and continues to pull off, and twist around until he has made a nice nest or bed. Sometimes they undoubtedly walk a few yards to get the material for a bed, but as a rule, where the foliage is so dense, they simply sit down and pull the material about them

After carefully examining the sleeping-quarters we followed on, dividing into three groups as the gorillas seemed to have done, but we had much difficulty in trailing them because elephants had been tramping all about.

One of the pygmies on my right suddenly spoke to the others, who darted forward as fast as they could go I could hear the other pygmies, then the noise of an animal, then blows. When I reached them I found they had killed a wild pig that had been caught in a snare. After they had tied it up, two old men were left behind to carry it while we continued our hunt. Not more than a half mile farther on we could look across a little valley. On the opposite side a boy had seen the vegetation move and he was sure gorillas were there We watched closely and, finally, with the binoculars

Photograph by E. T. Engle

LUNCHEON ON THE TRAIL NEAR MT. NAKALONGI.

RAVEN STANDS IN THE CENTER, WHILE THE PYGMY HUNTERS SQUAT AROUND THE FIRE.

Photograph by H. C. Raven

GORILLA BEDS.

GORILLAS USUALLY FEED UNTIL DUSK, THEN SITTING DOWN AMONG THE FOLIAGE THEY USE THEIR LONG ARMS TO PULL DOWN LEAVES AND VINES, ON WHICH THEY REST IN APPARENT COMFORT. IN RAINY WEATHER THEY TAKE ADVANTAGE OF SHELTER AFFORDED BY FALLEN TREES AND DENSE FOLIAGE.

I could see a black arm reaching up to pull down the bushes. We stole quietly down into the valley and then worked around so that we could come up-wind toward the feeding gorillas. We had first sighted these gorillas about noon, but it was 2:00 P.M. when we approached them. There were several, perhaps nine, as we had seen nine nests. They were quiet except for an occasional short grunt, indicating, I believe, that they were feeding quietly or perhaps telling their whereabouts to others of the group. They had moved slightly from where we first saw them and now were in low forest, the trees of which were fairly buried by lianas, many of whose stems were six inches in diameter. Underneath was a tangle of stems of thick undergrowth, so that in some places we could not be sure, on account of the irregularity of the terrain, whether we were looking at the ground or into the trees. There were many fresh signs of gorillas and we could see the place where one had sat down to eat. We felt the earth and found it warm; the animal had been there just a few seconds before. We were now right among them, and could hear them in three directions. Then I caught a glimpse of one in a tree, perhaps thirty feet from the ground.

I had with me a 30-30-calibre Savage rifle and also a 22-caliber rifle, the cartridges of which were less than an inch in length. In these tiny 22-caliber bullets I had drilled a hole and put in a small dose of highly poisonous potassium cyanide. If this actively poisonous substance could be introduced into the gorilla, whether his hand or head or body, he would drop dead within a few seconds. However, it was a question whether the heat generated in the bullet would not disintegrate the cyanide so that its poisonous action would be lost.

Using the 22-caliber rifle, I fired at the arm of the gorilla in the tree. Immediately there was a bark, screams, and wild commotion through the vegetation, as the gorillas rushed away. We rushed after them and found a few drops of blood from the one that had been hit. This one we carefully stalked. None charged or rushed at us; they were apparently thoroughly frightened. We followed cautiously

until about 5:00 P.M., when we had to give it up in order to find our way to a trail before dark.

It was evident that the cyanide had not worked on the animal, but the question arose as to whether it probably would die before morning. Early next morning, therefore, we took up the trail again and followed all day. The gorillas had gone on feeding, including the one that had been hit. He was apparently none the worse for the wound, which of course was not bleeding on the second day. Probably that wound did not do as much harm as a bite from one of his friends, received in play, or a stab from a broken branch.

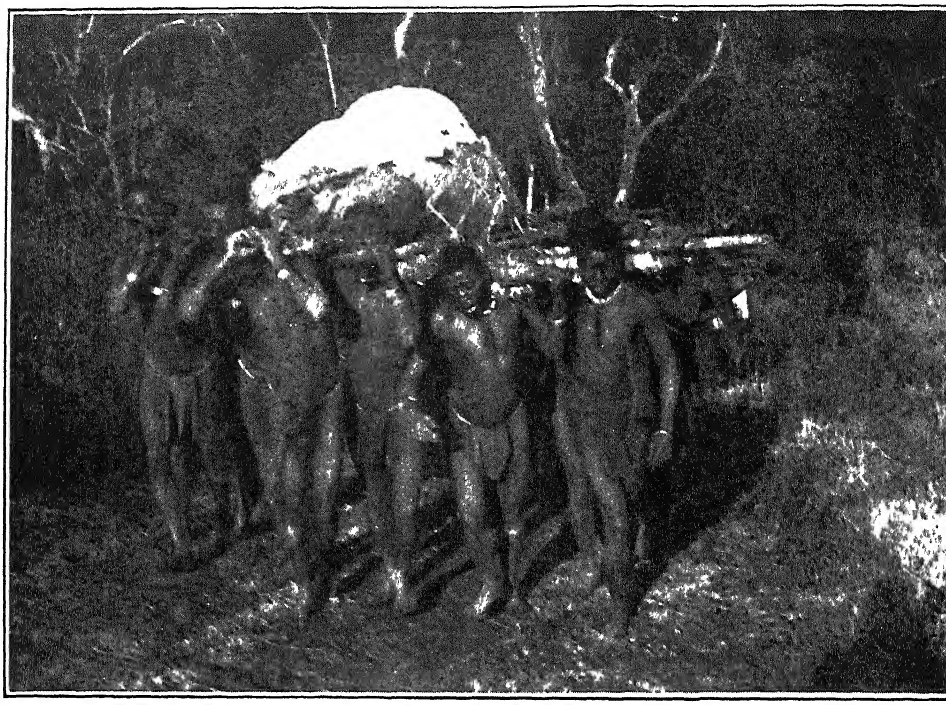
After several days of hunting near camp I decided to go farther up into the mountains to reach a place called Nakalongi. This was an all-day walk. I had with me several pygmies and a personal boy as well as a few porters. It rained most of the afternoon and was raining when we stopped at a little beehive-like hut high on the side of the mountain in a bean patch. To the west were hills covered with grass but in every other direction the hills and gullies were covered with dense forest. The natives immediately set to work to build for me a little dome-shaped hut of the coarse grass that grew round about. Its diameter was about the same as the length of my bed-roll but it shed the rain. Cold gray mist filled the valleys and often shut off everything more than twenty yards away. I ate my dinner at night crouched beside the fire with all the natives that could crowd in, then went into my own hut to sleep.

As soon as it was dawn we were up and shortly afterward set out to hunt. Most of the men remained in camp but four pygmies accompanied me. We first climbed up the mountain through a mass of cold, wet bracken, then de-

Photograph by H. C. Raven

WILD HONEY.

THE PYGMIES OF THE KIVU CLIMB A BIG TREE BY LASHING A SAPLING TO IT. THEY ARE HERE SHOWN PASSING DOWN HONEYCOMB FROM A HIVE WITHIN THE HOLLOW TRUNK.



Photograph by H. C Raven

THE DEAD MONARCH ON HIS BIER.

scended into a ravine through virgin forest so dark that it seemed like twilight. After about a half-hour of walking, very difficult on account of the steep and slippery ground, we came upon gorilla tracks and saw the remains of chewed-up stems The forest had been so cold and wet that it was impossible to tell whether the material had been chewed that morning or the day before. We followed on, however, and soon found tracks that had not been dripped on from the branches above. Farther on we saw signs that we knew were not more than a half-hour old. About an hour from the time we began to follow the trail we were passing diagonally down a steep slope toward a tiny stream Across the ravine sixty or seventy yards away, we saw the vegetation move and we caught glimpses of an animal between the branches Then we must have been seen or heard, for there was a sudden short bark. We followed across the stream and up the steep slope, climbing with difficulty where the gorillas could pass with ease. It was much more difficult for me, with shoes, than for the bare-footed, strong-toed, unclad natives, and still easier for gorillas with powerful bodies, short legs, and long arms. Man's long legs are suited to the erect posture and not well adapted for going through under-brush, where he must be doubled up much of the time

We were now getting close to the gorillas; we knew there was not a large troop, perhaps only three or four, but there was one big male among them, as we knew from the tremendous power in the bark he had given. The pygmies were nervous, saying that he would rush at us. We had gone less than three hundred yards from the stream and were still going through dense underbrush when suddenly the rush materialized with a terrific roar and shriek. The pygmy that was crouched down ahead of me, cutting the vegetation, sprang back and raised his spear, while I stood ready to fire. But like the other gorilla, this one stopped short, and did come into sight, although there seemed to be more ferocity in this animal. We continued on the trail and in a short time he rushed at us again. This time he was directly at our left, not ahead of us. Here the forest was a little more open and we could see perhaps ten or fifteen yards, but still he did not come within sight though we could see the vegetation move.

Finally we started up the slope. One pygmy went ahead of me, holding in one hand his spear and in the other his little sickle He passed beneath a fallen tree and I had just stooped

under this tree when the gorilla, closer than any time before, gave a terrific roar. I was afraid I was going to be caught under the tree but I managed to step forward and raise myself. As I did so I could see the great bulk of the gorilla above me and coming straight at me. I fired at his head as I might have fired at a bird on the wing. The impact of the bullet knocked him down and I wheeled to the pygmies, yelling at them not to throw their spears. I feared they would spoil my specimen. But they in turn shouted to me, "Shoot! shoot!" The gorilla was not dead When I looked around he was standing up like a man, it was plain to see that he was stunned I fired again and he dropped lifeless exactly fifteen feet away.

This animal was the most magnificent I had ever seen, weighing 460 pounds He was black and silver-gray, a powerful, courageous creature, determined to drive off intruders from his domain Upon closer examination I found this giant primate as clean as could be The long, shaggy hair on his head and arms was as if it had been combed only five minutes before. The silver-gray hair on his back was short and rather stiff.

Then came the time for quick action, for the specimen must be embalmed within a few hours It must be got on to the trail, the trail must be widened from a foot to ten feet up and down steep mountains for about twelve miles I sent a note to my companions in camp, telling them that I had secured the gorilla and asking them to send more porters I sent another boy to call up the natives that had come into the mountains with me While I examined the fallen gorilla, some of the pygmies were starting to make a bed or framework of saplings on which to carry him These saplings were of strong, hard wood and very heavy. Three long saplings were placed about eighteen inches apart and numerous cross-pieces then lashed to them with vines. The gorilla was lashed on the top of this litter.

By about three in the afternoon we had the gorilla out on the trail where I could embalm him We then wrapped him in a large canvas tarpaulin and made him more secure on the litter. I refused to leave him at night for fear a leopard or other animal might attempt to eat the flesh, so the natives made a little grass hut for me right there on the trail. More porters arrived the following morning and I detailed several to go ahead to widen the trail The gorilla and litter together weighed more than six hundred pounds. However, the natives started off chanting and went along for some distance at fairly good speed. After getting my paraphernalia packed in the loads I followed and caught up with them as they were trying to get up a very steep incline, where there was scarcely any foothold among the rocks and mud. I had told them that we must reach camp by nightfall, but it was soon evident that this would be impossible As a matter of fact, it took two and a half days, during which there

Photograph by J H. McGregor

THE NAKALONGI GORILLA IN CAMP.

Photograph by H. C. Raven

WHERE THE GORILLAS CAMPED FOR THE NIGHT.

RAVEN IS SITTING BESIDE ONE OF THE GORILLA BEDS.

were several severe electric storms that the natives claimed were caused by my having killed the "king of the mountain forests." They said the same thing happened when someone killed a very large elephant. At night we simply had to sleep in the forest in whatever shelter we could make of leaves and branches, but it was always wet and cold.

Many of the natives ran away as soon as it got dark and I never saw them again, but as this was the main trail between Lake Kivu and Nakalongi, there were natives passing along at intervals, and some of these were persuaded to help carry the gorilla. When we arrived at camp we continued the work of preservation and all took part in the making of photographs.

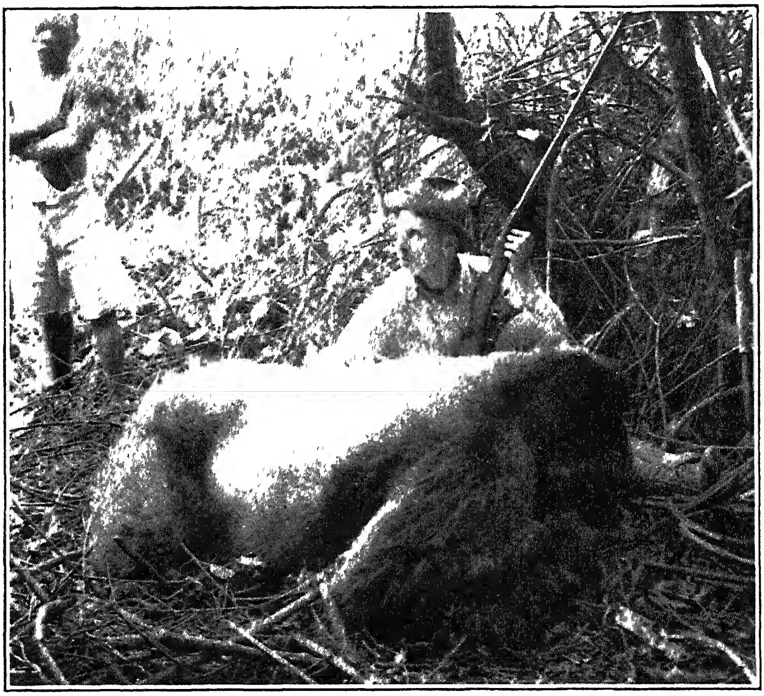
Meanwhile the rest of us in camp had kept in touch with Raven by means of messengers, so that when the gorilla arrived all was in readiness for its reception. We heard the tumult and chanting in the distance and soon the porters struggled up the slope to our camp, while the chants grew louder and fiercer. We could see the gigantic man-ape in his white funeral wrappings, his immense abdomen swelling high above his mighty black chest. Finally as the bier came opposite our main tent the toiling pall-bearers raised the chant to a climax. With a mighty heave they raised the bier above their heads and then, taking a step backward, they let it down to the ground. No wonder the whole neighborhood was excited and we most of all. After that Raven consented to stay in camp for a couple of days before beginning the quest for Number 2.

The taking of the second gorilla was in this wise. Late one afternoon (August 23rd) I was standing on top of the hill behind Mr. Vierstraet's house, strug-

gling to make a pencil sketch of the immeasurable panorama of mountains and lake, when from the forest a little way behind me came the sharp bark of a gorilla There could be no mistake that it was a gorilla, so I hurried down the hill and across the field to the camp to tell Raven But meanwhile a native had come to tell him that gorillas were near by and he had left camp immediately In a few minutes he sent back one of the two natives to guide McGregor and myself. About three minutes' walk from our camp brought us to a corner of the forest where the gorillas were preparing to make their camp Raven was already there and had caught glimpses of several of them He was not intending to kill any that night, as it was already too dark in the forest to get a good shot and he had reason to believe they would stay there all night.

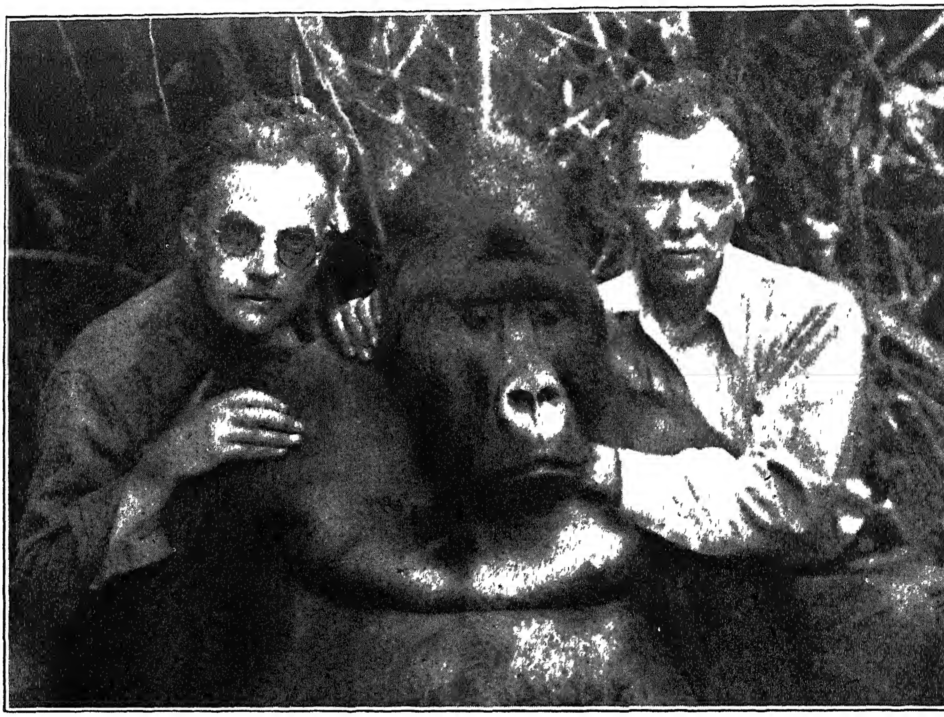
With the utmost care, for fear of disturbing them, we peeked over the nearby bushes and saw the branches waving where one of the big ones was making his bed by bending down stems and sitting on them. Then we could see one or two black bodies with long arms very deliberately climbing a tree. We watched with the greatest eagerness until it grew dark and then sneaked back to camp Late that night Raven, believing that the gorillas would be sound asleep and wishing to determine their exact positions, took a couple of natives, his gun and a flashlight and with great skill crept up quite close to them, heard their stomachs rumbling in their sleep and got away without disturbing them Early next morning he left with two natives, promising to send after us at the earliest possible moment, his object being to kill a big female first and then, if possible, let McGregor get cinema views of the rest.

Unfortunately for Engle, he had generously walked down to Bukavu on the



Photograph by J H. McGregor

THE PROSTRATE GIANT OF TSCHIBINDA.



Photograph by H. C. Raven

PRIMATES ALL.

day before with a band of porters to secure supplies for us, so that to our great regret he missed this intensely interesting occasion. McGregor and I stood on the top of the rise to the left of our camp; through our field-glasses we could distinctly see the branches move as the gorillas stirred about. We heard a shot, a sharp bark, then silence. A few moments later the native came toward us and beckoned and we started with the cinema camera. We sneaked quickly up a rear pathway and found Raven crouching under a great low-branching tree, with several gorilla beds under and near this tree and many smaller ones in the branches above us. Less than forty feet away several gorillas were hidden in the bush and we in turn were screened by a curtain of vines and bushes, with a couple of irregular openings for peepholes. From about 8:30 to 11:30 that morning we crouched in that spot, moving hardly at all and only with the greatest caution to avoid cracking a twig or rustling a leaf. McGregor crouched in front, holding up the cinema ready to start it in an instant. Raven crouched behind him with the gun, I a little to one side and two natives behind me. On the whole the two or three gorillas left there were strangely quiet. As we watched we could hear and see one of them beating its breast and making the strange sounds that one of our natives thought were made by slapping the hand against the thigh. At times we could see a large one, probably a female, leaning back on the bushes and now and again beating its breast. Once a big face peered through, looking straight toward McGregor, but before he could start the cinema it was withdrawn

As time passed it seemed strange that the gorillas did not slink off into the thicket, as they were so adept in doing,

without making a sound. After a long time Raven whispered to the two natives and they went away on long detours to the right and left They slunk off as quietly as the gorillas themselves, each one after a time coming back to whisper his report Then Raven quietly gave the word for us to move forward. Less than thirty-five feet in front of us (the distance being measured later) we found the dead body of a great gorilla, lying face downward, resting on his folded arms and knees The other big one, who had been waiting all morning for its mate or relative to wake up and go ahead, had now vanished.

Raven then told us that early that morning a very large male had appeared momentarily but he had not shot it, as he had already secured a large male and was now in search of a big female. Behind the male followed a broad face, which he took to be that of a large female and he had taken a quick shot at the face, his object being to shoot the animal through the head. There had been a loud bark, followed by the flurry of fleeing gorillas, then complete silence, and he thought that somehow he had missed the animal But there the gorilla lay dead before us

McGregor and I were intensely elated, but Raven was deeply disappointed and dejected, for two reasons: first, our second and last mountain gorilla was a male like No. 1, not a female as he had believed on account of its having been with a still larger male. Secondly, the single shot had narrowly missed the face and, the animal being on all fours, the bullet had passed obliquely downward through the neck and chest, thus probably tearing the great blood vessels upon which Raven was depending to carry preservative to all parts of the body.

However, there was very much to be

Photograph by H C. Raven

HEAD OF *GORILLA BERINGEI.*

done and done quickly. First we raised up the dead giant into a sitting position, pushing him against the stout bushes where he had died. How clean and beautiful to us was the velvety black skin of his great face and how grave and calm the expression of his large, deep-set brown eyes! Although it was indeed a pity to kill so noble a living monument of past ages, we had not murdered him wantonly and for sport This gorilla was destined to be, though unconscious of it, a missionary of science; for no one except those blinded by prejudice and ignorance could look at his titanic Jovian head and his mighty arms and hands without realizing that the creature partook of the nature of man, a fact which our natives were intelligent enough to realize

Such were our thoughts as we made numerous cinema pictures of our precious gorilla. But time was passing all too rapidly and it was necessary to transport the animal back to camp where it could be injected with preservatives It happened awkwardly enough that at this time we had had to let most of our first lot of porters go home and the second lot had not yet arrived. So we sent an SOS to our good friend Mr Vierstraet, asking him for a gang of his farm laborers and then went back to camp for a hurried lunch

By the time we returned Mr Vierstraet's men were already cutting a broad path leading down the hill from the spot where the gorilla lay to the corner of the field at the left of our camp. In about half an hour also a number of saplings had been cut down, trimmed and lashed together to make a bier, upon which the huge body was rolled Then with a mighty heave thirty or more men got their shoulders under the projecting poles and the funeral procession started It was surprising to see how enormous the dead giant looked on his bier, as the crowd struggled up the slight rise leading to camp, while McGregor got cinema

Photograph by H. C. Raven

ENGLE PUTS UP HIS PRESERVES.

Photograph by H. C. Raven

HANDS OF GORILLA AND MAN.

THE GORILLA'S FINGERS ARE WEBBED. NOTWITHSTANDING THE SHORTNESS OF THE GORILLA'S THUMB, IT CAN BE BROUGHT INTO CONTACT WITH THE OTHER DIGITS WHEN THE HAND IS FLEXED.

records of them What a pity there was no way to record the weird droning chant of the pall-bearers as they came up the hill, or their final shout as they lifted the great burden from their shoulders to their upraised arms and then let it down in front of the camp. Meanwhile every white person in the vicinity and crowds of blacks swarmed around the dead gorilla.

One of the natives did something which surprised me considerably. He was evidently trying to convey to another man the idea that the gorilla was very big He took a stick and held it against his own upper arm, holding his thumb and forefinger at the right distance from the top. Then he placed the stick in position along the front of the gorilla's upper arm to show the great difference in favor of the gorilla. Here, I thought, is the beginning of physical anthropology, and for that matter, here is where physical anthropology has too often stopped, with a mere measurement of differences

The next business was the preservation of this very difficult subject. As Raven had feared, the great vessels were cut by the bullet and he had a tedious and dif-

ficult job to locate the cut ends, tie in the cannula and make separate injections through the carotid and femoral arteries

In the course of these operations it was deemed advisable to empty the digestive tract, partly because the enormous mass of material in it would under the present circumstances be difficult to sterilize and prevent from fermenting. As this was done, pail after pail was filled first with the contents of the stomach and then with that of the lower sections of the tract. The material from the stomach contained an immense amount of succulent green material, which appeared to remain largely undigested even in the lower end of the tract. No parasites were found until the lower bowel was reached, when small round worms, that Dr. Engle thought might be *Ankylostoma,* and tapeworms, similar in appearance to the human types, appeared in great numbers. A series of these parasites was preserved by Dr. Engle for future study. No external parasites were found. The vermiform appendix (which the anthropoids share with man) was present. In general, one saw that here was a digestive system of practically human type, but with the abdomen expanded to hold a huge quantity of vegetation. Thus the swelling abdomen, the huge quantities of ingested vegetable tissue, the cross-crested molar teeth and stem-cutting tusks afforded certain analogies with hoofed herbivores, such as tapirs, mastodons and wild boars, but the deeper anatomical features were far more like those of man.

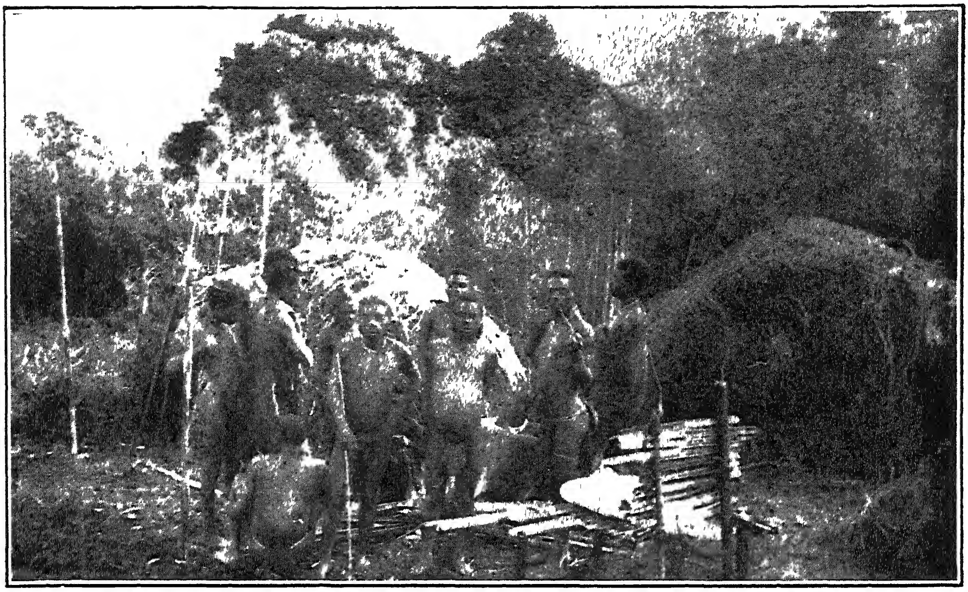
Engle and I took many detailed finger and palm prints of this gorilla, which had loops and whorls of surprisingly human appearance. I should like to have a professional palmist read the lines in this gorilla's palm. McGregor made plaster molds of the face and entire bust of the animal, as well as molds of the hands and feet. The latter proved to be much larger than those of the female secured by Akeley and are most imposing objects.

Photograph by J. H McGregor

SOLE OF THE LEFT HIND FOOT OF GORILLA.

IN WALKING THE GREAT TOE SPREADS OUT FROM THE OTHERS BUT, ESPECIALLY IN THE RELAXED CONDITION, IT CAN BE DRAWN IN NEAR TO DIGITS 2–4 THE TOES ARE WEBBED FARTHER OUT TOWARD THE ENDS THAN THEY ARE IN MAN.

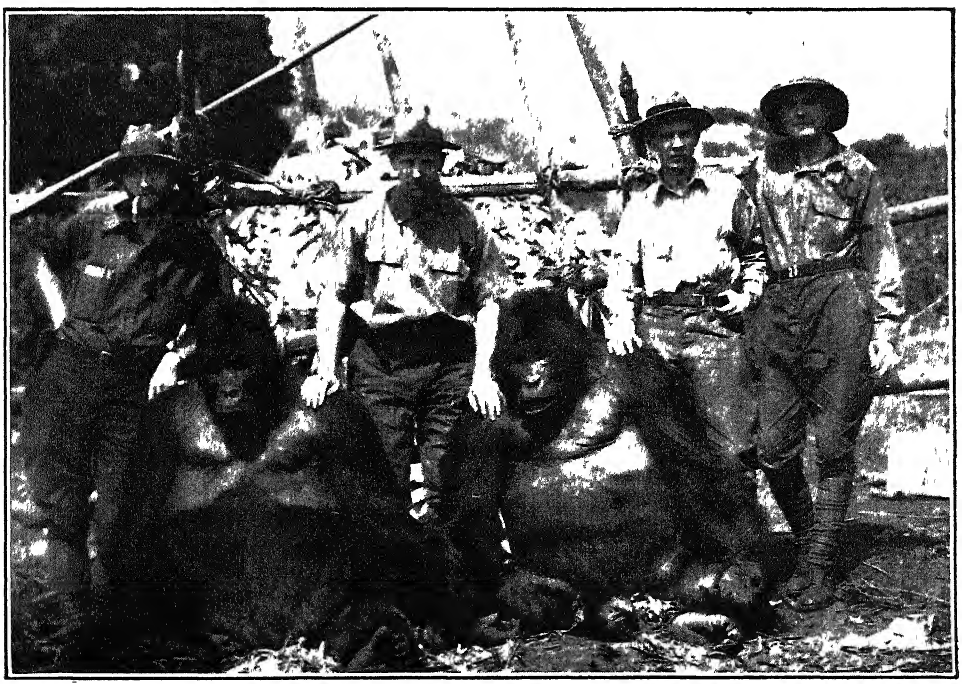
After the killing of the second gorilla I redoubled my efforts to discover fresh gorilla traces in the immediate neighborhood of the camp, while Raven and Engle searched in distant localities, as



Photograph by E. T. Engle

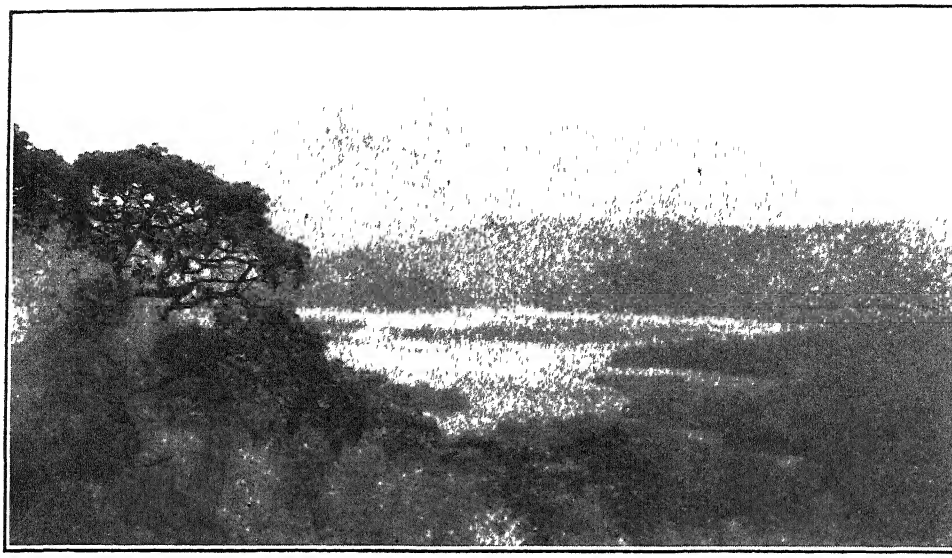
IN CAMP ON MT. KAHUSI.

THE BAMBOO STICKS HAVE BEEN FASHIONED INTO A RUDE TABLE WITH WIND-BREAK. TWO OF THE PYGMY HUNTERS ARE SMOKING NATIVE PIPES.



Photograph by H. C. Raven

CLOSING DAYS AT TSCHIBINDA.



Photograph by H. C. Raven

LOOKING NORTH FROM THE NAKALONGI TRAIL.

we were now keen to get some cinema records before leaving this region. On several days I took a few Batwa, promising them large rewards if I could even catch sight of a gorilla. They harangued me earnestly each time, but all I could make out was "No gorillas . . . elephants." But Raven told them to go with me and they did so. We went up hill and down dale but never came across a fresh gorilla sign, although several weeks before they had been quite numerous. The only souvenir of a gorilla that we saw on the entire strenuous climb was in a charming little open field of small green bushes high up on the mountain, with gigantic dark trees all around in the background. At one spot a gorilla had sat down on a clump of bushes to bask in the sun and perhaps to doze a little. Then he had risen, idly sheared off a tall twig and drawing it between his great canine teeth had stripped it entirely of its fragrant outer layer and tossed it away for us to find. *"Ngagi"* (gorilla), said the Batwa, and my hopes were revived, even if this were an old trace. And it was some compensation to see the little old gnome of a Batwa tell me the story in pantomime.

Meanwhile Raven and Engle had made a long excursion to Mt. Kahusi in the hope of finding gorillas in the bamboo forests and getting a chance to make cinemas of them. Although they found no trace of gorillas they saw many interesting things, such as native iron-smiths fashioning their iron spearheads. Fairly fresh elephant tracks were abundant

Just before leaving Tschibinda I told all this to Mr. Van der Stok, general manager of the plantations and experimental farm.

"Why, of course you didn't find many fresh gorilla traces at that time," he said, in substance. "Every year in September when the elephants come to Tschibinda, the gorillas move out and are gone until after the end of December, when they return"

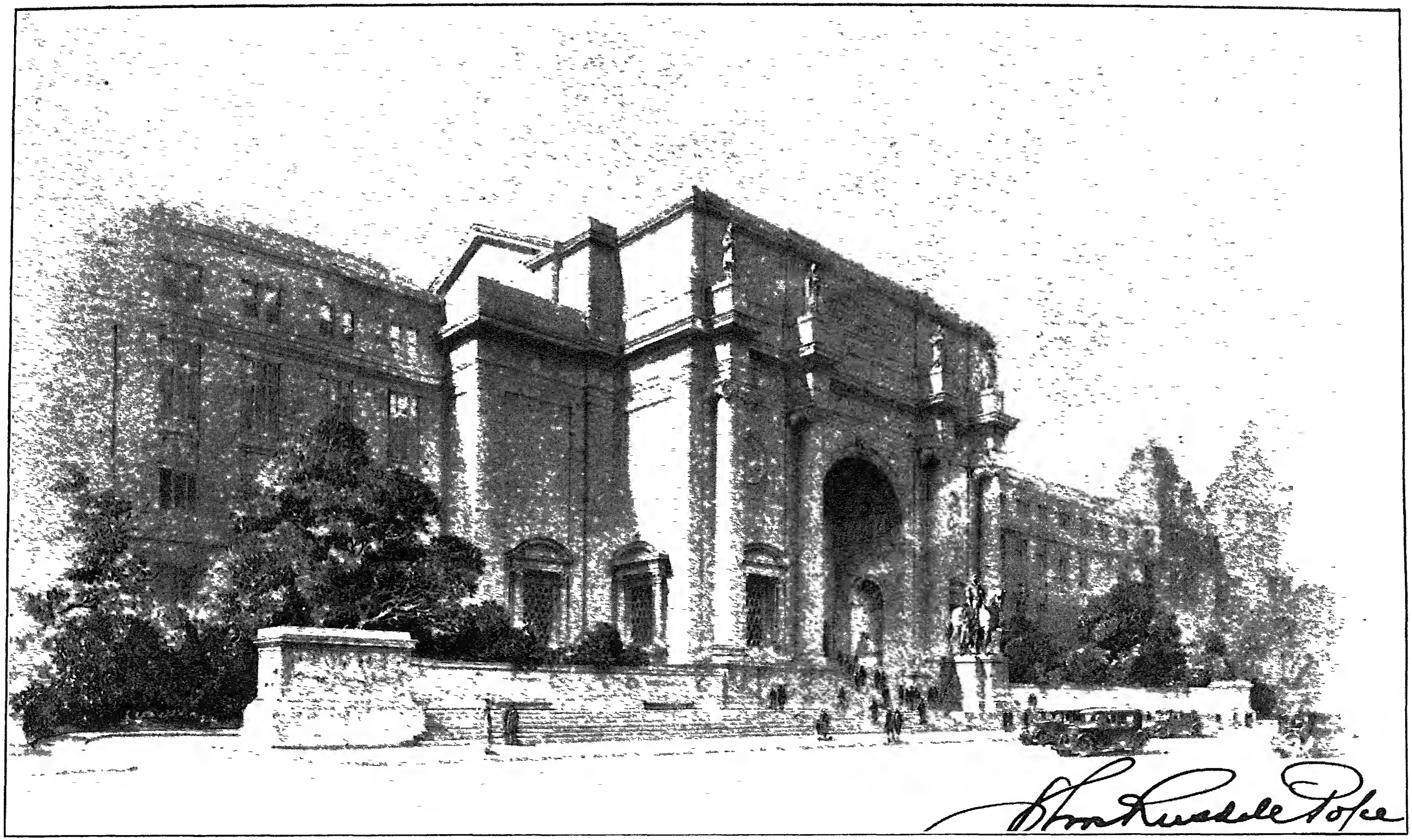
Then I realized that the Batwa had been imploring me not to waste my time and theirs But my colleagues are sceptical about all this, urging that the forest is a very big place, that after all I was seldom more than a mile or two from

camp, and that I might have passed quite close to gorillas without their presence being betrayed.

Our stay at Tschibinda was prolonged far beyond our expectations, chiefly because we did not dare to ship our second gorilla until we had done everything we could to prevent it from "going bad" on the long journey home The cutting of the great vessels above the heart had made it very difficult to preserve the entire body properly At last, however, the body had been injected in many places and it seemed to be resisting sufficiently well the forces of decay. Raven therefore wrapped it up like a mummy, covered its bandages with melted paraffin and after considerable correspondence obtained a camion, in which he took the body all the way down to Uvira at the head of Lake Tanganyika, whence it was shipped by rail and boat to Dar-es-Salaam and eventually forwarded via Marseille to New York. But in spite of all our efforts the long journey through the high temperatures proved very hard on this specimen, which arrived in New York in poor condition. Fortunately, the other four of the five gorillas obtained by Raven in East and West Africa all arrived in excellent condition and have since been studied by several specialists.

On account of the delay at Tschibinda we were forced to give up our plan of proceeding to the upper end of Lake Kivu and of visiting the Parc National Albert which lies to the north of this lake. There we had intended to try for motion-pictures of the living gorillas in the Parc. But it was necessary that at least three of us return to New York before February first, and judging from our experience of unexpected delays it would take a couple of months to make the long journey across Africa either to the French Congo or some other part of the range of the lowland gorilla of West Africa.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)



THE NEW YORK STATE ROOSEVELT MEMORIAL

THE ARCHITECT'S DRAWING IS REPRODUCED BECAUSE THE RECENT COMPLETION OF THE BUILDING MAKES A PHOTOGRAPH UNSATISFACTORY. THE EQUESTRIAN STATUE OF ROOSEVELT IS NOT YET IN PLACE.

THE PROGRESS OF SCIENCE

THE NEW YORK STATE ROOSEVELT MEMORIAL

On Sunday, January 19, the board of trustees of the New York State Roosevelt Memorial held the dedicatory exercises in that building

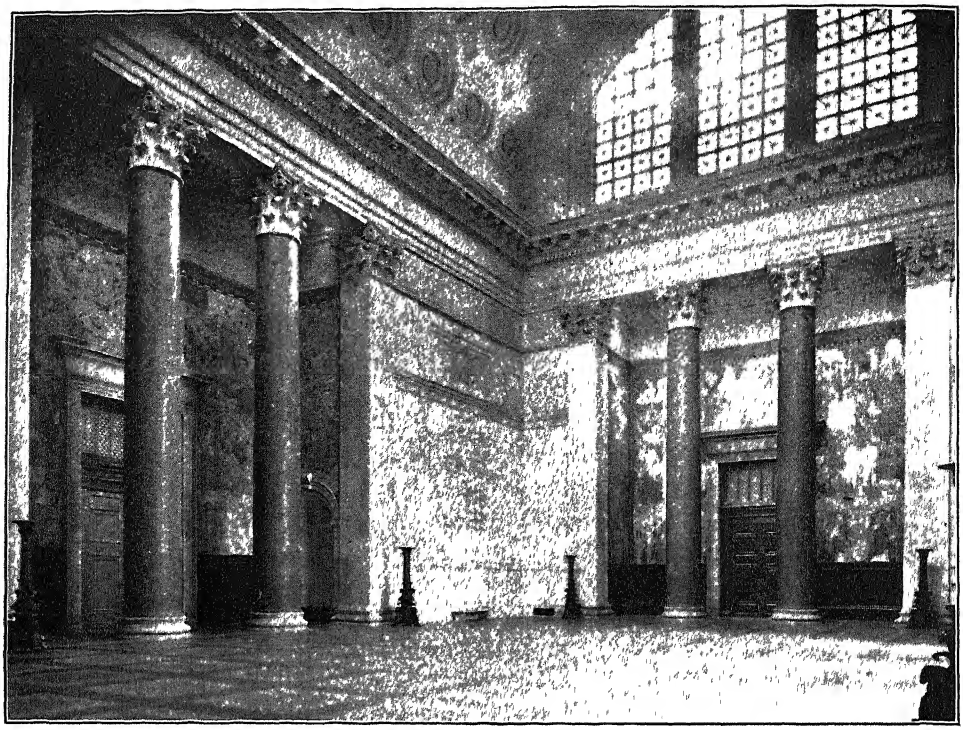
President Roosevelt delivered the principal address, "A Tribute from the Nation." Participating with him in the exercises were Governor Herbert H. Lehman and Mayor Fiorello La Guardia, who spoke on the relation of the memorial and its effect on state and city, respectively. These speakers were followed by A Perry Osborn, who outlined the "Guiding Principles for Memorial Administration," and by Colonel Theodore Roosevelt, Jr, with an address of "Appreciation." Dr. James R. Garfield, the closing speaker, spoke on "Roosevelt the Man"; and the exercises closed with a benediction by Dr. Charles W. Flint, a trustee and chancellor of Syracuse University.

After the death on January 6, 1919, of Theodore Roosevelt, the late Professor Henry Fairfield Osborn, in cooperation with leading New York newspapers, advocated the erection of a memorial to Roosevelt that would be educational in character. In 1920 Governor Smith appointed a commission to examine the question of the proposed memorial, and later this temporary commission rendered a report A second commission was appointed in 1924 by Governor Smith, who stated that he would like to see a plan for a memorial "which would for all time stand as a visible expression of the recognition of the services of one who had been most active in the welfare and development of our State and Nation."

Several years of intensive study by the commission resulted in the development of the plan which has now become a realization. The factors decided upon as essential to the plan were: First, to interpret the character of Roosevelt as a naturalist and citizen; second, that the form of the memorial must primarily be an educational institution, as no other form would adequately memorialize the broad humanitarian intelligence that Roosevelt possessed, and that every facility should be incorporated which would give students an opportunity to study nature, know its phases from all angles, and be led to emulate the extraordinary knowledge that Roosevelt attained; third, that the memorial should suggest a lofty standard of idealism through lines inspired by models chosen from the golden age of architecture, that there should be evolved a design which would symbolize the spirit of Roosevelt and by its impressiveness infuse those ideals for which Roosevelt strove and many of which he gained.

As soon as the form of the memorial was decided, efforts were made to secure the necessary funds for its construction, and in 1924 the legislature enacted a law providing $250,000 with which to defray necessary expenses, and subsequently provided the sum of $3,500,000 for the work. After a competition in which many prominent architects participated, John Russell Pope was selected as the architect.

The program of competition stated that "the nature lover should be stressed by monumental architecture, sculpture and mural paintings. The design should symbolize the scientific, educational, outdoor and exploration aspects of Theodore Roosevelt's life rather than the political or literary." In Mr. Pope's plan these features are blended most harmoniously A monumental structure, graceful in every line and inspired by the stately designs of the old Roman archi-



MEMORIAL HALL

tecture, it conveys to the beholder an impression of spaciousness and enduring strength.

The façade is modeled on the triumphal arches of ancient Rome. The entrance arch rises to a height of sixty feet above the base, and is flanked on either side by huge granite columns supporting heroic figures of Lewis, Clark, Audubon and Boone, outstanding characters in early American history.

These prominent features, together with its deep recesses, shadows and reflections, and its mammoth bronze screened window, most successfully unite the exterior with the interior.

From the practical and educational standpoint the building is splendidly equipped with classrooms, exhibition rooms, a lecture hall that will seat six hundred people, a hall for the display of the resources of New York State and a room devoted to Rooseveltiana. At the right of the entrance vestibule are located the administration offices or Trustees' Room, while at the left is a group of superbly finished panelled butternut wood interiors, forming a suite of rooms to be known as the Statesmen's Rooms. A cafeteria and lounge are located in the basement, and from that floor direct access can be had to the platform of the Eighth Avenue Subway.

The façade of the building is executed in pink granite. On the parapet wall surrounding the terrace are carved inscriptions indicative of the fullness of Roosevelt's life as follows: Ranchman, Scholar, Explorer, Scientist, Conservationist, Naturalist, Statesman, Author, Historian, Humanitarian, Soldier and Patriot Upon the pedestals supporting the exterior columns and the pedestals flanking both ends of the terrace, which is 350 feet in length, Edward Field Sanford, Jr., the sculptor, has carved in bas-relief the figures of animals native to America and Africa. A vehicular drive-

way adjoins this terrace, passing about the rear and leading to the first floor entrance

In the center of the terrace, immediately in front of the great entrance arch, upon a polished granite pedestal, will be an equestrian statue of Roosevelt with two accompanying figures on foot, one an American Indian and the other a native African, representing his gun bearers and suggestive of Roosevelt's interest in the original peoples of these widely separated countries This group will rise to a height of thirty feet above the sidewalk It is the work of James E. Fraser, the well-known sculptor, who designed and executed the four statues that surmount the great columns on the main façade.

Passing through this entrance, one steps into the Memorial Hall itself, a conception of grandeur and dignity in harmony with the spirit of Roosevelt's lofty ideals and fearless character. This hall, exclusive of recesses, is 67 feet wide by 120 feet in length. The floor is richly patterned in marble mosaic, the walls, to a height of nine feet, being of St. Florient cream marble surmounted by mellowed limestone extending to an elaborate Corinthian cornice and culminated by an octagonal barrel vault, reaching to a height of 100 feet above the floor. At either end of this vaulted ceiling the walls are penetrated by large circular-headed windows which furnish the hall with ample daylight. In order to avoid the deteriorating effects of direct daylight on the murals, the architect has skilfully designed recesses in the walls at three sides of the room. These three recesses with a fourth containing the entrance arch have each two Roman Corinthian columns forty-eight feet high supporting the entablature. The shafts are executed in a red antique marble.

In the three great recesses have been

—Copyright, W A. Mackay

A SECTION OF THE AFRICAN MURAL IN THE WEST RECESS OF MEMORIAL HALL. IT IS THE WORK OF WILLIAM ANDREW MACKAY, WHOSE MURALS IN THE HALL COVER AN AREA OF OVER 5,000 SQUARE FEET.

placed mural paintings which form a most important part of the general decorative scheme and in themselves successfully portray the varied activities of Theodore Roosevelt. The artist, William A. Mackay, has given the north recess over to the subject "The Panama Canal," the south recess to "The Treaty of Portsmouth" and the west recess to "African Exploration." In these murals, covering a total area of 5,230 feet, the artist has selected and skilfully presented the outstanding achievements rendered by Roosevelt both to our country and to the world.

In the spaces within the memorial quotations from Roosevelt's writings and sayings have been arranged under four headings as follows: Nature, Manhood, Youth, The State.

For more than sixteen years the late Professor Henry Fairfield Osborn had given his time, energy and thought to produce a structure which he felt would best memorialize Theodore Roosevelt. With these ideas constantly before him he developed a planned structure of such grandeur and beauty, combined with utilitarian purposes, that it is believed it stands without a peer. Within its walls one immediately responds to the thoughts which Roosevelt felt most applicable to mankind.

The trustees of the American Museum of Natural History, who will later control the operation and maintenance of the memorial, have pledged themselves, in their acceptance of the memorial, to carry out the educational purposes laid down by their late President Osborn for their guidance; to regard the sacredness of the memorial, to keep faith with the people of the state; and to be true to the ideals of Theodore Roosevelt.

George N. Pindar,
Secretary of the Board of Trustees

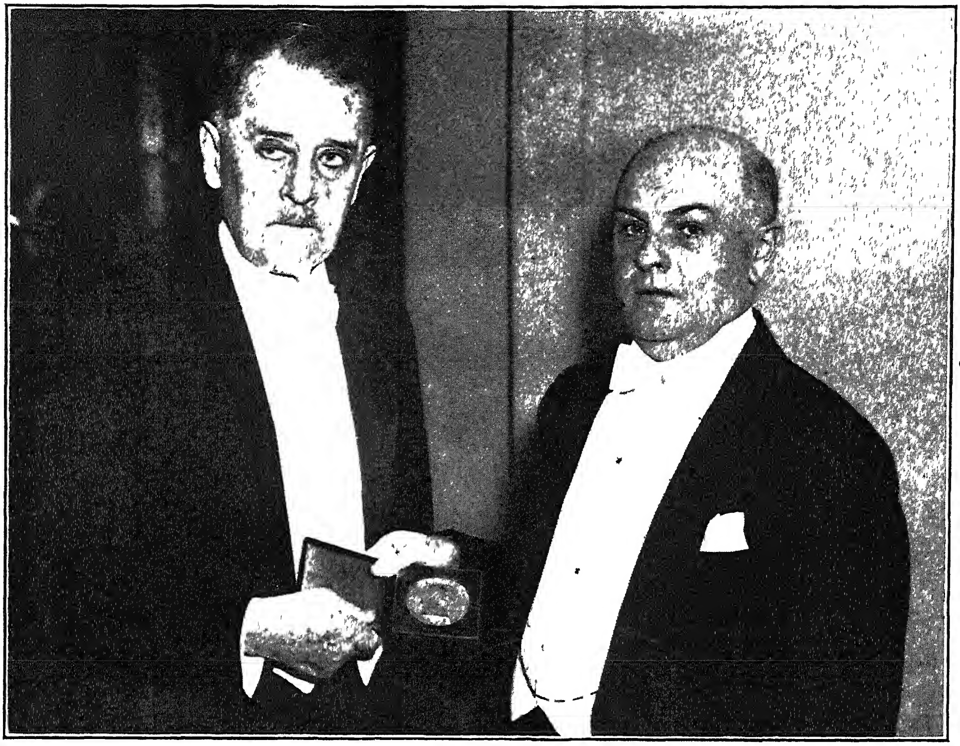
LEWIS BUCKLEY STILLWELL, EDISON MEDALIST FOR 1936

The Edison Medal, the highest honor conferred by the American Institute of Electrical Engineers, is awarded for meritorious achievement in electrical science, electrical engineering or the electrical arts. Within the broad scope thus indicated, the medal has been conferred upon eminent scientists such as Bell and Millikan, inventors such as Thomson and Pupin, educators such as Ryan and Kennelly, engineers such as Westinghouse and Sprague, and others equally preeminent in the field of applied electrical science.

Lewis Buckley Stillwell, the recipient in 1936, is distinctively of the engineering group, the well-recognized functions of which are economic planning, technical design and execution. The distinction of Stillwell's career lies in the novelty and magnitude of the projects with which he has been entrusted, the extent to which they have involved far vision of specific as well as general economics and the welfare and convenience of large groups of the public, and their ultimate conspicuous success. He is fitted for the large and varied problems and many such have come to him.

Indicative of his conspicuous talent is the fact that at thirty years of age, as general engineer for the Westinghouse Company, he was in general charge of the planning and installation of the electrical equipment for the first development of Niagara Falls power and its transmission to a distance. This was an enterprise which was not only record-breaking and revolutionary in many of its aspects, but which immediately attained success, and, in its use of alternating current, has served as a pattern for the enormous subsequent expansion in this and other countries of long distance electric transmission

Of equal magnitude and equally noteworthy in their advances over existing methods were his plans for the installation of the first electrical equipment for the Manhattan Elevated Railways, and

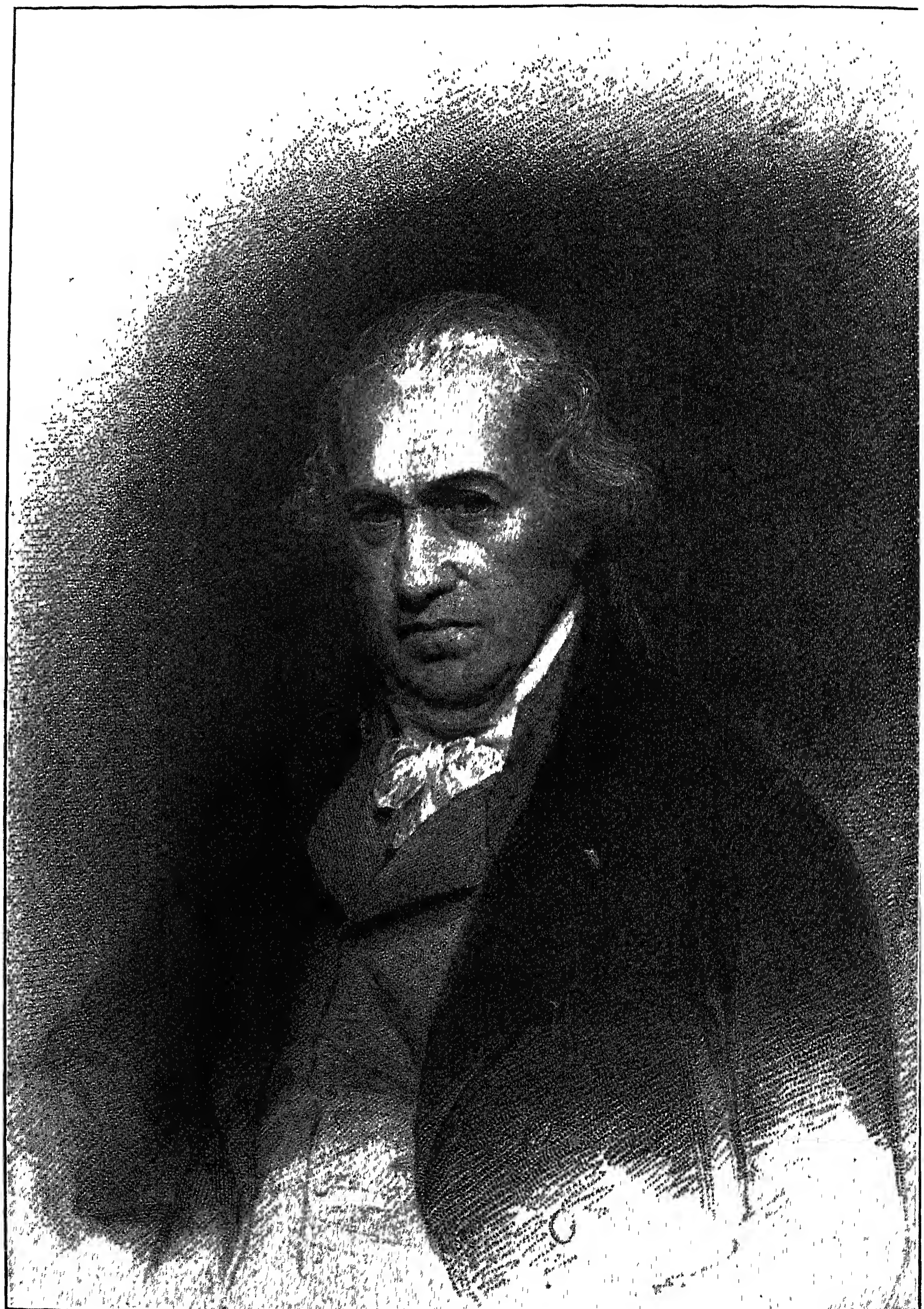


World Wide

PRESENTATION OF THE EDISON MEDAL
TO LEWIS BUCKLEY STILLWELL (LEFT) BY EDWARD B. MEYER, PRESIDENT OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

particularly that for the first subway system in New York City. He has been intimately identified with many of the projects involving mass transportation in and near New York, all involving new methods and enlarged facilities, and all marked by conspicuous success. Transmission and transportation, in large terms, have been his specialties, and many important projects in these fields have come to him.

Although such a professional record would of itself have merited the Edison Medal, Mr. Stillwell's contribution to the profession has extended much further in the high standard of professional conduct which not only have guided his own career, but which he has enunciated on many occasions and otherwise supported to the building up of the high code of professional conduct prescribed by the American Institute of Electrical Engineers. He has a deep sense of the opportunities for public service open to the engineer, and the consequent responsibility upon him to give of his best and in accordance with the highest ethical and professional principles. He frequently has found time to give to the profession and to the public many results of his careful study and analysis, and to take active part in movements looking to a more unified position and activity of the engineering profession in public affairs. Many of his published papers have dealt with major national problems, as for example, "The Relation of Hydro-electric Power to the Conservation of the Nation's Resources." Several other such papers constitute excellent examples of the type of service which a competent engineer with a high



JAMES WATT

sense of public duty may render to a government sincerely in search of guidance. A further paper on "The Status of the Engineer" marked the beginning of a long-continued effort to bring together in some coordinate form the common interests of the various branches of the engineering profession, and which culminated in the establishment of the American Engineering Council, the important channel for the exchange of information and service between the entire engineering profession and the public, governmental and other agencies

J. B WHITEHEAD,
Dean of the Faculty of Engineering
THE JOHNS HOPKINS UNIVERSITY

THE WATT BICENTENARY CELEBRATION IN THE UNITED STATES

THE two hundredth anniversary of the birth of James Watt, whose improvements of the steam engine led to the train of events which constituted the industrial revolution, was celebrated on January 19, 20 and 21 with a three-day program arranged under the joint auspices of Lehigh University, the Franklin Institute of the State of Pennsylvania, the American Society of Mechanical Engineers and the North American Branch of the Newcomen Society of England

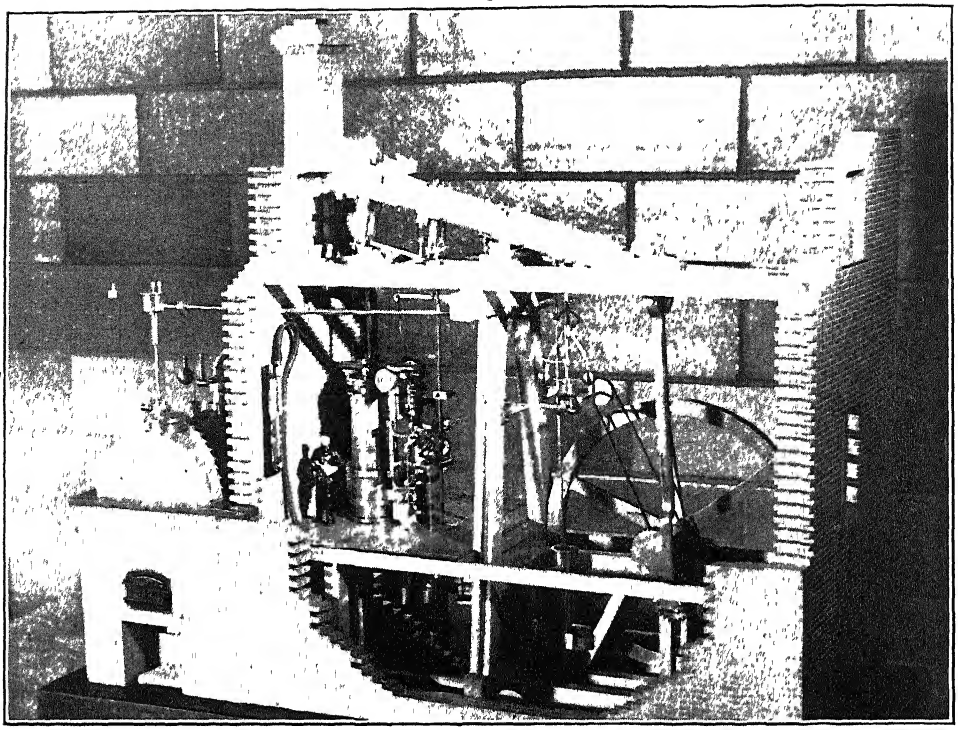
In the development of this celebration the committee issued an early invitation to the engineering societies, to scientific and technical bodies, to historical associations, to local engineering clubs and societies and to the engineering colleges, inviting them to participate in the celebration by sending delegates to the meetings at Lehigh University and at the Franklin Institute, or by holding their own simultaneous meetings.

The response to this invitation was wide-spread, particularly on the part of the engineering colleges in the United States and Canada, where more or less generally, some class assembly, convocation or student society meeting was dedicated to the celebration, by appropriate lectures bearing on James Watt and the industrial development which followed his pioneering achievements.

The celebration opened on Sunday, January 19, with an international broadcast from the Science Museum, South Kensington, London, England Colonel Alexander Elliott Davidson, aid-de-camp to the late King George and president of the Institution of Mechanical Engineers, reviewed Watt's accomplishments and extended greetings to the participating bodies in the United States "Old Puff Puff," the Watt engine built in 1799, rattled through her paces under the direction of Mr. H W. Dickinson, director of the museum. The Franklin Institute followed immediately with a broadcast bearing greetings from the sponsoring bodies and with a display of the models in their justly famous Hall of Prime Movers.

The next day, January 20, the celebration was continued at Lehigh University with a three-session program. At eleven o'clock, Robert L. Sackett, dean of the School of Engineering of the Pennsylvania State College, presided over a panel discussion on "The College Graduate in Industry" Represented in the discussion were the personnel directors of prominent industries and members of engineering faculties from neighboring colleges

At three o'clock, Arthur M. Greene, Jr., dean of the School of Engineering of Princeton University, presided over a "Colloquium on James Watt," where papers dealing with the life and work of Watt, his association with Matthew Boulton and with the significance of that notable partnership, were presented respectively, by George A Orrok, Professor Joseph W. Roe and Dean Dexter S Kimball. The addresses were followed by a demonstration of Newcomen and Watt engine models built at the university.



Photograph by W. Mansfield White

MODEL OF THE WATT STEAM ENGINE AT LEHIGH UNIVERSITY

The evening session was opened by the induction of Clement C. Williams, president of Lehigh University, into the North American Branch of the Newcomen Society of England. Addresses were made by William L. Batt, president of the American Society of Mechanical Engineers, who spoke on "Watt—Symbol of the Industrial Age," and by William C. Dickerman, president of the American Locomotive Company, whose subject was "Some Problems of a College President."

The celebration was concluded on January 21, with two sessions held in Philadelphia. During the afternoon, the Franklin Institute was host to the participating bodies. Following an exhibition and demonstration of Newcomen and Watt engine models in the Hall of Prime Movers, the Newcomen Society conducted a meeting presided over by Charles Penrose, vice-president for North America of the Newcomen Society of England "Greetings of Great Britain" were extended by Sir Gerald Campbell, K.C M G., British consul general, New York, and "Greetings of Scotland—Land of James Watt's Birth," by Andrew Baxter, Jr., president of Saint David's Society of the State of New York. Mr. Penrose himself addressed the group on the subject, "Monday, January 19, 1736, in North America," depicting Washington as a lad of four and Franklin as a man of thirty at that time.

From a historical point of view, Dr. Thomas Jefferson Wertenbaker, Edwards professor of American history at Princeton University, spoke on "James Watt: Inventor and Pioneer." Addresses bringing personal experiences in the development of the steam engine for the electric industry and in the development of the steam locomotive were given by

James Alward Seymour and Samuel M. Vauclain, respectively.

The final session of the three-day celebration was a formal dinner held at the Bellevue-Stratford Hotel in Philadelphia, under the auspices of the Franklin Institute, President Nathan Hayward presiding, Conrad N. Lauer, toastmaster. A "Eulogy on James Watt," prepared by H W. Dickinson, of London, was read by Colonel C. E. Davies, secretary of the American Society of Mechanical Engineers. Julian P Boyd, secretary of the Historical Society of Pennsylvania, addressed the gathering on "Civilization Since James Watt." "Steam in its Relation to Marine Engineering, the Electric Industry and to the Railroads" was discussed respectively by Rear-Admiral Harold G. Bowen, George A. Orrok and William C. Dickerman.

Papers presented at the Lehigh University program are printed in the February, 1936, issue of *Mechanical Engineering*. Those presented at the meeting of the Newcomen Society will be published in the proceedings of that body.

The Watt Bicentenary Committee follows: Fred V. Larkin, director of mechanical engineering, Lehigh University, *chairman;* Henry Butler Allen, director of the Franklin Institute; Clarence E. Davies, secretary of the American Society of Mechanical Engineers; Charles Penrose, vice-president for North America of the Newcomen Society of England.

F. V. Larkin,
Chairman

THE MEASUREMENT OF COSMIC RAY INTENSITY

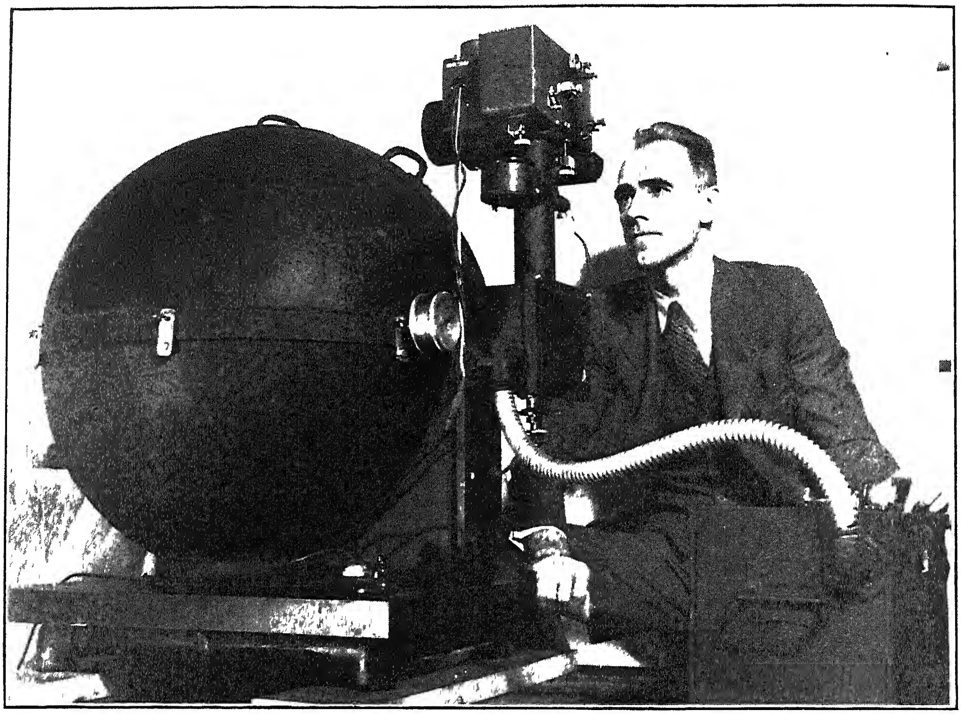
Variations in cosmic ray intensity, a subject of wide scientific interest, are being studied at the Massachusetts Institute of Technology this winter with one of the seven new cosmic ray intensity meters which are to be used in a world-wide investigation of cosmic radiation under the auspices of the Carnegie Institution of Washington.

These new instruments, each of which weighs more than a ton, were designed and built at the University of Chicago under the direction of Dr. Arthur H. Compton, with Dr. A. W. Simon, also of the University of Chicago, and Professor Ralph D. Bennett, of the department of electrical engineering at the institute.

The purpose of these extremely sensitive meters is to measure the variations from normal in cosmic ray intensity and to discover, if possible, the source of the rays by correlation of these variations with such manifestations as sidereal time, sun-spot cycles, terrestrial and solar magnetic storms and the rotation of the galaxy. The meters will also be used to study the nature and origin of the bursts of energy released in the form of thousands of cosmic ray particles traveling downward together at enormous velocities; the total energy in each burst surpasses by thousands of times that of any other known atomic cataclysm.

In designing these instruments the problem was to produce mechanical means of making continuous records of the behavior of cosmic rays for long periods without attention. Each of the new meters employs a small motor to drive a moving strip of photographic film in a camera which records the measurements over a period of months.

Measurements of cosmic ray intensity are made possible in this instrument by their effect on very pure argon gas, which is confined in a 14-inch steel bomb at a pressure of 750 pounds to the square inch. To avoid interference from other forms of radiation, such as those from radioactive materials in the earth and air, the argon gas bomb is buried in the center of a large steel sphere containing 2,500 pounds of lead shot, which acts as a shield against undesirable radiation, but which is easily penetrated by the cosmic rays.



ONE OF THE COSMIC RAY INTENSITY METERS
THE COMPARTMENT AT THE LOWER RIGHT CONTAINS BATTERIES, WHICH WILL OPERATE THE METER FOR A YEAR, AND THE CONTROL SWITCHBOARD AND STANDARDIZING METERS. PROFESSOR RALPH D. BENNETT, WHO ASSISTED IN ITS DESIGN, IS SHOWN WITH THE APPARATUS.

The cosmic ray meter at the Massachusetts Institute is already in operation in a laboratory in the department of electrical engineering under the supervision of Professor Bennett. After being tested under various conditions, the instrument will be taken next summer to Mount Evans, Colorado, where at an elevation of 14,265 feet above sea-level it will be operated as one of the instruments in the world-wide chain of stations. Professor Bennett, Gordon S. Brown and Henry A. Rahmel took the first model of the meter to the top of Mount Evans for tests last year. In the face of snowy gales, violent electrical storms and freezing temperatures they carried on investigtaions for several weeks that aided in the final design of the meters

One meter is now in operation at the field station of the Carnegie Institution at Cheltenham, Maryland. Another is on its way to Peru, where it will be installed at the magnetic observatory at Huancayo. Another is to be sent to the interior of the Mexican highlands, and one will be taken to the Danish observatory in the northern Greenland ice fields. Still another will be stationed in New Zealand, and the seventh at the University of Chicago

J J. R.

THE SCIENTIFIC MONTHLY

APRIL, 1936

MODERN ENERGY SUPPLIES

By Dr. GUSTAV EGLOFF
DIRECTOR OF RESEARCH, UNIVERSAL OIL PRODUCTS COMPANY, CHICAGO, ILLINOIS

PROGRESS of mankind through the ages has been measured by his increasing ability to utilize energy outside himself to do his work. This is true to-day, although it may seem that man has so much power at his command that at times it dislocates industry, causing unemployment. This, however, is no indictment of power itself; it is merely an ironic manifestation of our temporary inability to use it properly.

Since power is the mainspring of human progress, it is well to consider its sources. How long will they last, and how can we make the best use of them? The primary source of energy is the sun, and our most important power sources are composed of organic material which was grown in the sunlight of past ages and is now buried in the earth, where it has been converted into coal, oil, gas, peat and oil shale in the heat and pressure of nature's underground laboratories.

There can be no question that there are energy sources potentially available for man's every need for thousands of years at the present rate of consumption. The sources now used by man in the order of importance are: coal, oil, water power, natural gas, wood, man, animal and wind, with traces of peat, oil shale, power alcohol, internal heat of the earth, direct solar energy and future sources of energy such as tide power and differential in sea-water temperature.

COAL

Before coal was used to a great extent as a heating unit, the forests of many countries suffered and were practically denuded in order to furnish fuel and charcoal for the fast-growing iron and steel industry. The early history of coal as used by man is unknown. Scattered throughout Greek and Roman history there are references to the use of "stones that burn." Remains of coal fires were found in Britain by the explorers of the early Roman camp sites. It is in the twelfth and thirteenth centuries that we begin to find notice being given to the use of coal which was either washed up on shore by waves or found in outcroppings in the hills. Immediately following these discoveries an era of coal utilization ensued which was marked by the digging of holes in the ground to mine the coal.

As coal became highly competitive with wood as a fuel in England in the early centuries of its extensive use, it was found that burning coal was against the laws of God and man, and some men went to jail for using it.

Coal is available as bituminous, semi-bituminous, lignite and anthracite. The earth contains over 7,400 billion tons, of which mankind is using about 1.3 billion

tons a year. At present rates of consumption, coal is available for man's needs to cover a period of the order of 6,000 years.

Coal as such is not of much importance until it gives up its energy in the form of power. The heat from coal is used to furnish electrical and steam power for driving locomotives, ships and turbines. Other useful products are obtained from coal, under special heating conditions, such as gas, coke, motor fuel, pitch, asphalt and other substances used in the chemical and plastic industries. In order to generate one horse-power of electrical energy, in 1920 four pounds of coal were used; in 1935, only one pound of coal per horse-power was required, and improvements are still being made to cut the quantity of coal needed per horse-power of energy output.

Of the total energy used in the United States last year, 48 per cent. came from coal.

One of the important uses of coal is to convert it into gas, and yearly the gas-making industry produces over 500 billion cubic feet of gas in the United States. At the present time, coal is shipped by cars to the different cities where it is converted into gas, liquid and coke; and coke in turn converted into water gas or carbon monoxide and hydrogen or used for metallurgical purposes. A more economical method of producing gas for heating and lighting purposes from coal would be to produce the gas at the mine and then pipe it to consuming centers of population. This would bring about an enormous saving in the cost of gas or energy production and eliminate the transportation of coal, relatively high in ash and water having no heating value, and much of the soot of cities, which is so detrimental to society. Gas production at the coal mine is not being carried out in the United States; however, in the Ruhr district of Germany, gas is produced at the mine and then transported by pipe line hundreds of miles for industrial and home use. In some countries the coal gas is compressed into cylinders and used as motor fuel and sold much like gasoline at filling stations.

A development that is going on in Germany and England for the better utilization of coal is to convert it into gasoline and other oils by the hydrogenation process. Two commercial plants, one in England, another in Germany, are in operation to liquefy coal into oil under hydrogen pressure of the order of 4,000 pounds per square inch and temperature of 900° F. It is reported that every ton of coal processed yields five barrels of gasoline or oil.

Another important catalytic process developed in Germany is the production of gasoline, kerosene, gas oil, waxes and lubricating oils through the reaction of water gas or carbon monoxide and hydrogen derived from coal and water. The oils produced can be converted into high octane motor fuel to the extent of 85 per cent. of the oil by the cracking process. These two processes are relatively expensive to operate at the present time and are commercial, due to governmental subsidy. The cost of producing motor fuel is of the order of more than four times that of gasoline produced from petroleum.

It is interesting to note that there was a flourishing coal-carbonizing industry in the United States composed of 56 plants in 1859, which were forerunners of the oil industry, to produce kerosene and lubricating oil. In that year the Drake oil well came in, and coal carbonization for kerosene and lubricant production died out. Some of the distillation plants were used in the oil industry to fractionate Pennsylvania crude oil. History may repeat itself, if and when our crude oil supplies fail, so that our

refineries will operate on oils from coal. Whatever change takes place will be a transition and not abrupt.

From the world's store of coal of 7,400 billion tons we can produce by the hydrogenation and cracking process enough oil to supply world needs for over 24,000 years, at the present yearly requirements of 1.5 billion barrels of crude oil.

Oil

To-day we know that hydrocarbons are widely distributed through the earth, whether they be coal, petroleum, natural gas, oil shale or peat. Petroleum is particularly wide-spread, despite the general belief that there is a very limited quantity available for future generations. From the geographic standpoint, petroleum may be located in any part of the world. For example, it has been found in the Arctic Circle, in the jungles of Colombia and Borneo on the Equator, and in the temperate zone of the United States. Oil has been located high on the slopes of the Andes in Peru, 13,000 feet above sea-level, and on the ocean floor of the Pacific in California, and in the desert land of the San Joaquin Valley. As an illustration of the diverse places where petroleum occurs, one need but refer to Chicago. True, it would be expensive to recover, but Chicago is built upon a deposit of dolomitic limestone, which contains for each square mile 7,500,000 barrels of oil—therefore, the 200 square mile area in Chicago contains 1.5 billion barrels of crude oil.

In the last year alone more than 40 new oil pools were discovered, which has added over 1,250,000,000 barrels of crude oil to our reserves.

In the first six months of 1935 over 10,000 new wells were drilled, of which about 70 per cent. were oil producers, with 6 per cent. as gas wells and the balance dry holes. During the ten previous years the average oil producers represented 61 per cent. of the wells drilled, a striking illustration of the effect of science upon oil location.

Crude oil is the second largest energy source in the world. It is being produced at the rate of 1.5 billion barrels a year and ranges as it flows from the wells from an almost pure gasoline to a solid at ordinary temperature. Crude oil shows colors from white to black and also of the rainbow. The odors of crude oil vary widely from the perfume odor of sandalwood and pungent camphor of the sickroom to the vile odors that even put a self-respecting skunk in the shade.

Since the foundation of the oil industry in the world, about 26 billion barrels of crude oil have been produced. This volume of oil would not fill a hole in the ground a mile deep and a mile square. Geologists estimated in January, 1934, that over 13 billion barrels of crude oil are available by present producing methods in the United States, or a supply for fifteen years. Between 38 and 115 billion barrels of crude oil are left in the earth and not recoverable by present methods used in the United States. An average of these volumes is a supply of oil for about 85 years if one would mine the oil in a similar way to coal as they do in Alsace Lorraine, France, and Hanover, Germany. Moreover, the earth itself may be used as a giant still. By burning a part of the oil in the sand, distillation of the oil would bring the vapors to the earth's surface where they may be fractionally condensed to the products desired. Jesse A. Dubbs, an American, invented this method over 40 years ago, and recently, Russian oil technologists have carried out the process in their country with some order of success.

The oil industry is producing crude oil at the rate of a billion and a half barrels a year to supply not only the 35,000,000 motor cars in the world with gasoline and lubricants, but also the manifold

energy requirements of society. The oil industry is honeycombed with technologists from every branch of science, in order to improve oil location, drilling, storage, transportation in over 100,000 miles of pipe line and refining into finished products.

One of the greatest conserving forces in the world is the cracking process, which converts oils that do not contain any gasoline as such, by the application of temperatures of 950° F. and pressures of about 300 pounds per square inch, into high antiknock motor fuel with yields from 60 to 80 per cent. By saving crude oil, as a natural consequence, cracking has decreased the cost of locating oil, drilling, pipe lines, storage and refining facilities. This is estimated as a saving of $1,300,000,000 capital investment on these items, in addition to the yearly value of the crude oil thus conserved.

If refiners had been forced to produce without cracking the 18 billion gallons of gasoline needed to operate the 25 million motor cars in the United States, the quantity of crude oil required to produce this amount would have been double that actually refined, *i.e.*, approximately 900 million more barrels would have been required to satisfy our motor fuel needs.

Petroleum through the years has been an increasing competitor of coal as an energy producer. It now represents over 22 per cent. of the total energy used in the United States. About 45 per cent. of the total crude oil refined in the United States during 1934 was gasoline which was used in our motor cars, airplanes, motor boats and tractor engines. The quality of gasoline has been steadily improved through the years; a relatively recent revolutionary discovery in the oil industry being the production of polymerized gasoline. This motor fuel comes from the gas produced by the cracking process, which heretofore has been used as a fuel under stills or boilers. There is available yearly 300 billion cubic feet of cracked gas having a potential of over 1,000,000,000 gallons of 81 octane gasoline. Polymerized gasoline upon hydrogenation will produce 100 octane gasoline and make it possible for airplanes to hurtle through the air at the rate of over 500 miles an hour; thus the trip from New York to Chicago in less than two hours can be accomplished.

With thousands of geologists, chemists, physicists and engineers searching for oil, the amazing success of collective effort in locating new fields and drilling to depths of over two miles with but 2° off the vertical and finding oil, augurs well for the future of the oil industry in that we will have ample supplies of oil for our every need for more than a century.

Water Power

One of the oldest sources of energy for man has been the waterfall. Since the invention of the water wheel for capturing the power of running water by some ancient Egyptian on the banks of the Nile, the refinements and uses of the present water wheel would render it unrecognizable to the inventor. The first water wheels were probably used for grinding corn. At the present time our water turbines have reached a 94 per cent. efficiency, which is the best power-producing machine that man has so far achieved. In the United States to-day the percentage of energy derived from waterfalls is 8.0 per cent. of the total used.

The total potential horse-power from waterfalls in the United States has been approximately estimated to be 127 trillion horse-power yearly and we are actually using 42 trillion.

Water, as far as we know, is a perpetual source of potential power, and may come into its full utility at a distant date when other energy sources may be exhausted.

The difficulty in using much of the

water power available lies in the fact that it is on the fringes or remote from consuming areas. General belief is that all man has to do is to place some wheels in the stream of water and, lo and behold, he has cheap energy. Not so, when one considers the high installation cost and electrical transmission over distances to large consuming communities and the incident loss of energy during its transmission. Water power as a source of energy in many areas is more expensive than that derived through the generation of steam power by coal, oil or natural gas.

Giant undertakings by man are represented in the Boulder Dam project, the Norris Dam and the one proposing the use of the tides at Passamaquoddy, Maine. This intends utilizing a tide frontal wave coming in at a height of 28 feet. This project, sponsored by the United States Government, will cost about $36,000,000. It will have a daily capacity of 200,000 horse-power from the energy of one of the world's highest tides, and furnish electrical energy for homes, farms and industry by tapping the gigantic and inexhaustible force of the ocean. This ebb and flow of tides has been an urge to man's inventive genius for centuries to convert it into useful work. Many projects have been advanced from time to time to harness tides such as those in the Chinese River at Tsien Tang, Severn River in England, estimated to be able to deliver 1,250,000 horse-power per day, the Coast of Brittany in France and the tidal basin at Passamaquoddy. The United States is the only country actually putting in a plant for the generation of electrical energy by tidal means.

An ingenious proposal has been made by Dr. Georges Claude, who has experimented with a semi-commercial plant in Cuba to utilize the warm water layer on top of the ocean by passing it into a vacuum, thereby generating steam and using the cold water layer of the ocean as the cooling fluid to condense the steam. Thermodynamically, this is a sound principle, but only time will tell whether it will be economical and competitive with other sources of energy. However, from a potential energy source, utilization of temperature differential in waters of the earth reaches astronomical figures.

Natural Gas

Natural gas is not alone produced as such but also accompanies crude oil. In progressive oil fields where it is possible, the excess gas is pumped back into the oil sand to maintain pressure and lengthen the life of the field.

Natural gas is one of the ideal energy-producers, due to its composition of methane and ethane hydrocarbons, which lend themselves particularly to usefulness in gas engines, steam production and industrial and household uses because of its high heating value per unit volume. Natural gas represents 8 per cent. of the total energy used in the United States. Gas is readily transportable, and thousands of miles of pipe lines radiate from the gas fields, such as the Panhandle of Texas, Kettleman Hills in California, Oklahoma, Louisiana and Pennsylvania. A pipe line snakes its way clear from Texas to Chicago. Vast gas fields are used to supply not alone Chicago with energy, but also other cities, such as St. Louis. The volume of natural gas delivered to Chicago from Texas is about 100 million cubic feet per day. It is estimated that the Panhandle of Texas alone could supply the needs of their clients for over 200 years.

Outside of the United States very little natural gas is being used; however, there are vast volumes potentially available in different parts of the world. In the Persian oil fields, where there are no industries, something like a billion cubic feet

of natural gas is shot into the atmosphere daily. Vast quantities of natural gas also escape into the atmosphere in different oil fields of the world where no ready markets are available.

Natural gas is being produced at the rate of over 1.6 trillion cubic feet a year in the United States. The North American supply in present fields is estimated at 75 trillion cubic feet—or enough for about 50 years at present consumption rates.

Wood

History advises us that wood was the first heating and power source man ever utilized. A little over 300 years ago the early settlers of the United States were just beginning to use the forests for their energy supplies from the 900,000,000 acres of forest. Wood is still an important source of energy, as it represents over 7 per cent. of the total utilized in the United States during 1934. The percentage of wood consumption for the world as an energy producer is much higher than in the United States. Reliable data are lacking. However, in some countries, such as Roumania, which is a large oil-producing country, one can note that the steam locomotives used in that country are fired by wood, coal and oil. The wood-burning locomotives are used to keep the wood-choppers of Roumania employed.

In some parts of the world, wood is used to run motor cars and busses by converting it into gas. Italy has a number of passenger busses operating between Milan and Rome on gases derived from carbonized wood.

Due to modern research, wood can be carbonized into 40 gallons of tar per ton. This tar by the cracking process can be converted into 26 per cent. of motor fuel and 21 per cent. of Diesel oil, the balance being coke and fuel gas.

With heavy reforestation in the United States, we can in time build up enormous resources of energy, which can be utilized when other sources diminish or disappear.

Man and Animal

Man started out in this world with his own energy, which amounted to one eighth of a horse-power per day. It is not certain how long he relied upon his own energy. The first that he used outside of himself was probably the heat from wood. Then he corralled the jackasses around him, either in the form of some of his neighbors or the animals that he caught, and put them to work.

Man and animal power is not great when measured in terms of power used through the world from other sources. However, it is still a very substantial portion of the total, for in the United States it represents 5 per cent. of the energy used. It is much greater in other countries backward as far as the machine age is concerned. From the 2 billion people in the world and 85 million horses, mules and burros, in addition to an unknown number of yaks, water buffalo, elephants, dogs, camels, reindeer and oxen, the potential energy in horse-power per year for man and beast must be over 110 billion.

Wind

Man has used wind as a power source for years on end to the very present. Sailing ships and windmills have been the means of utilizing wind for his needs. Of the total energy used in the United States last year 1 per cent. was derived from the wind. Wind, as any one living in Chicago knows, is not very satisfactory from an industrial standpoint, since man has not yet been able to command the time for it to blow, outside of himself. However, some adaptations of the windmill have been made in recent years to generate electrical energy or hoist water for farm use.

In France and Denmark, countries low in potential power sources, the development of the windmill for electric power was given a strong impetus by the world war. The French windmills are built for strong winds, and there are some in operation capable of giving 300 horse-power output.

In 1932, a German engineer set forth the formidable plan of harnessing high altitude winds by building 1,400 foot towers to support vanes 524 feet in diameter. A unit costing $1,000,000 would supply the electrical needs of a city of 100,000 at a cost comparing favorably with steam and water power.

Another type of development which has been tried with varying degrees of success is the rotor tower. The driving force to the revolving towers is furnished by eddying wind currents. In 1926 Flettner applied this principle to the propulsion of a ship. The Flettner rotor ship towers were 60 feet high and 10 feet in diameter. The towers rotated at about 100 revolutions per minute, propelling the ship in the direction desired. Some rotors were installed in New Jersey to generate electrical power. The rotor power plant consisted of a number of large cylinders 90 feet high and 22 feet in diameter. This installation was calculated to produce 1,600 horse-power per day.

The energy potential available from the wind is enormous, but no really economic method has been devised so far to use it. Whenever the urge is great enough to utilize wind as a continuous source of energy, man's inventive faculty will undoubtedly find the way.

Peat

Peat has been used as fuel probably since the dawn of civilization. Its use was recorded by Latin writers during the conquest of northern and western Europe by the Romans. It has been burned for hundreds of years in Russia, Ireland, Finland, Denmark, Sweden, Holland and Germany, and also in the pioneer days in the United States.

The areas of peat land in various parts of the world are enormous in their extent and in the amount of peat which they contain. It is estimated that the peat deposits of the world are over 200 billion tons, of which Russia has about 65, Finland 38 and the United States 14 billion. The amount of energy produced from peat in the world is but a trace of the world's energy production.

Peat as nature produced it contains water and it is necessary to dry before use. By low-temperature carbonization, the world potential of peat tar is over 100 billion barrels, which can be converted by the cracking process into 35 per cent. motor fuel or a 75-year supply at the present rate of oil consumption.

Oil Shale

Oil shale deposits are located in many parts of the world. The principal ones on the American continents are those of the United States, Canada, Brazil, Argentina and Chile. They are also found in the British Isles, France, Jugo-Slavia, Spain, Sweden, Bulgaria, Germany, Italy, Switzerland, Esthonia and Russia. There are also considerable amounts of oil shales in Australia, China, Japan, Arabia and Syria.

The retorting of oil shale to produce oil, gas and coke is in commercial operation in France, Esthonia, Spain, Scotland, Australia and Manchuria. Oil production from shale is relatively expensive, and although a vast amount of work has been carried out in the United States endeavoring to find an economical process, none has survived because of the competition of coal and petroleum. The oil shale is mined, split into small pieces and put into retorts which are externally fired; the vapors from the shale are con-

densed and refined to marketable products.

A most ingenious oil shale plant operated for a number of years in Australia, which used the mountain of oil shale as a still. A horizontal shaft was drilled into the mountain, and a vertical shaft met the horizontal. A fire was started by the admittance of controlled quantities of air, the oil distilling out of the shale passing up through the mountain and into pipe connections at the top to condense the products. This is a cheap way of obtaining oil, but it threw so many men out of work, it is reported that the Australian Government stopped the process. There is no technical reason why this process is not a practical one and cheap to operate.

It is estimated that the United States has potentially available over 108 billion barrels of shale oil which can be converted into motor fuel, lubricants and other energy-producing products modern civilization calls for.

The total quantity of oil shale in the world is unknown. That it is huge is generally acknowledged. The world's potential shale oil production is estimated to be at least 300 billion barrels or 200 years' supply. By the use of the cracking process this oil would yield sufficient gasoline to operate all the motor cars in the world at the present time, for over four hundred years, with 180 trillion cubic feet of fuel gas and 11.3 billion tons of coke as by-products. The amount of shale oil produced in the world at the present time is insignificant as measured in terms of energy output.

Power Alcohol

Photosynthetic processes are the best means nature has of utilizing solar energy. Our society uses energy at a prodigious rate, and were it not for our vast stores of potential energy, civilization as operated to-day would be impossible. Much research has been done in recent years on power alcohol from crops; but if society had to depend upon alcohol and cellulose alone for power, it would require about 12 billion bushels of corn or its equivalent to produce enough alcohol to operate the motor cars in the United States alone. The volume of alcohol required would be about 30,000 million gallons, whereas the present production in the United States is 100 million. The enormous volume just given would not take care of the lubricants that our machines require. Alcohol can be converted, by a process called dehydration, into ethylene gas, which in turn can be catalytically polymerized into lubricants. To produce the volume of lubricants used yearly in the United States from corn would require over 2 billion bushels. Hence, 14 billion bushels of corn, or its equivalent, would be necessary to produce gasoline and lubricants for our energy requirements in motor cars and machines of society.

Power alcohol and alcohol lubricants would be at least five times more expensive to produce than those procured by present means from petroleum. Agriculture as a means of supplying modern society with its energy requirements for motor cars—which has been put forth by proponents as a relief for the economic ills of the farmer—would be tremendously expensive compared to present sources of supply. To rely on alcohol as an energy source would also be precarious, because of the uncertainty that is ever present in raising crops.

The amount of alcohol used as an energy source for the motor cars of the world is exceedingly small compared to other sources.

Direct Solar Energy

In considering the use of solar energy directly, man's necessities have not demanded a thorough investigation of the

possibilities. The methods by which solar energy may be used is well established in man's scheme of things, for it involves his food supply in the growth of plants, in the form of wood and in man's effort to utilize the sun as a direct source of power.

By direct utilization of the sun's heat, nature has the most efficient and yet the most baffling system ever worked before man's eyes. For all man's progress in finding out about nature, he has not yet been able to work out nature's most puzzling starch factory—chlorophyll—the green matter in living plants. During many ages the plants alone have been capable of utilizing the enormous floods of sunshine pouring upon the earth. Yet, that is but a small amount of the energy that has come to the earth from the sun.

Man has tried means of harnessing the sun's heat and utilizing it with more or less successful attempts ever since Archimedes used concentrated sun rays to set fire to the fleet of Marcellus at Syracuse. The chief difficulty in the use of direct solar energy for power has been due to storing of power until needed, and also to the intermittency with which the sun shines in most parts of the world. Sun power can be generated in boilers located in the desert on the border of arable land, and the power transmitted by electricity to consuming centers. A sun-power plant is in experimental use in Cairo, Egypt. The principle is the absorption and concentration of heat by means of parabolic mirrors which focus the heat on layers of water. The power from the plant was used to pump water for irrigation purposes.

If it were possible to convert into power all the solar energy that falls on the United States alone in the form of sunshine, it would furnish 7,000 trillion horse-power. At Mount Wilson Observatory, a 15-foot instrument with 30 lenses generates a temperature of 6000° C. In Russia efforts are being made to develop the practical harnessing of sun power.

Inventors and technologists have a real task ahead of them to work out economic methods of using the direct energy of the sun. However, we may rest assured that it can be worked out when the necessities of our social system demand it.

Internal Heat of the Earth

In many parts of the earth hot gases blow into the atmosphere in enormous volumes. They exude particularly in volcanic regions. The steaming crevices are caused by underground rivers coming in contact with volcanic fires. That this steam may be used for power has been demonstrated in Italy, where they generate 19,000 horse-power per day. In Sonoma County of California volcanic steam is used to generate electricity for local use. Other places not yet developed, but which have naturally occurring hot gases are the Valley of Ten Thousand Smokes in Alaska, Lassen Peak in California, Steamboat Springs near Reno, Nevada, and the Yellowstone Geyser Region.

Since nature has provided steam in these places from natural causes, one can assume that man could provide himself with power from the earth by drilling wells, either tapping hot gas sources or pumping water into the well, converting it into steam. It is well known that the temperature of the earth increases with increasing depth, the rate being less in older rocks than younger. The deepest well drilled by man so far is over two miles. The temperature gradient varies quite widely—some average 1° increase for every 65 feet in depth. A recent well drilled at Palestine, Texas, 9,000 feet

TABLE I
U. S. ENERGY PRODUCTION AND RESERVES

Energy source	Billion horse power production, 1934	Per cent. of total used in 1934	Reserves in million units	No. of years supply
(1) Coal	252,106	48.0	4,104,552 tons	10,000[1]
(2) Oil	117,572	22.5	10,000–13,250 bbls. known petroleum producible by present methods in known and proven fields.	11–15[2]
			38,526–115,736 bbls. petroleum remaining in producing formations of present known and producing oil fields after exhaustion of production by present methods.	44½–134
(3) Water Power	42,400	8.0	127,189 H.P.[3]	"Perpetual"
(4) Natural Gas	41,854	8.0	40,000	25[4]
(5) Wood	37,280	7.1	Enormous energy available if reforestation continues.	"Perpetual"
(6) Man and Animal	26,800	5.1		?
(7) Wind	6,990	1.3	Enormous	"Perpetual"
Total	**525,002**	**100.0**		

[1] Stanley Gill, "A Report on the Petroleum Industry in the United States," p. 297.
[2] *Ibid.*, p. 21.
[3] United States Power Survey, 1935, Interim Report.
[4] *Oil and Gas Journal,* March 14, 1935 (Valentin R. Garfias).

deep, showed a bottom temperature of 225° F. One deep well in the Kettleman Hills region produced 200° F. water at the rate of over 5,000 barrels a day instead of oil.

Can one say from these facts that our energy will ever be exhausted in any practical length of time?

ATOMIC ENERGY

From time to time some of the laboratories of the world have given forth the information that atomic energy will be available for man's use. As far as we now know, it requires more energy to crack atoms than the amount of energy given out. Hence we may not look upon atoms as a practical source of energy for man's requirements.

CONCLUSION

There are energy sources for man's every need for thousands of years, despite the fact that his demands have increased over forty fold in the last hundred years. Just how much energy will be required in a hundred, a thousand or a hundred thousand years hence is problematical. That it will be huge is certain.

Man has never failed in inventiveness to achieve the machines to use our vast potential sources to lessen society's labors. It is most likely that his future endeavors to lighten at least the physical load still further will meet with success.

The data of the energy consumption and supplies in the United States are shown in Table I.

PHYSICS, METAPHYSICS AND COMMON SENSE

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I. Physical Science in a Modern World

On this day in the twentieth century, when maladjustment seems to be a major characteristic of the entire world, when ideals and institutions alike seem to be trembling in their deepest foundations, though they rest on the traditions of many centuries, thoughtful people in all civilized countries are led to scrutinize the achievements of the human race with increasing misgivings. It is all very well for a modern mind to revel in the thrill of living in the most explosive and the most dangerously uncertain period in history. In more sober moments this same mind will, nevertheless, realize that the thrill is one of primitive savagery and not of enlightened civilization. Perhaps it will then turn to seek refuge in things inspirational that transcend the merely practical and material values of matters economic and political. Such are music, art, literature for a willing spirit that loves beauty; philosophy and theology for the roaming mind that delights in things unknown and mystical; natural science and mathematics for him who finds joy in consistent logic and symmetry of structure. But the mind that takes pride in calling itself modern will, no doubt, brush aside with ill-concealed impatience such achievements of the spirit, to point with genuine satisfaction to the material creations of science, and especially to its phenomenally successful applications in engineering and medicine. Here, indeed, is a wealth of visible accomplishment. Here are motor cars, airplanes, marvelous bridges and highways; floating palaces. Here are the telephone and the radio, the x-ray and the electric knife and innumerable other achievements of applied physical science and technical skill. Truly the scientific mind has made penetrating researches in many fields, all leading to an enrichment in human knowledge and to a multiplication of physical wealth. But has all this been a blessing? Is it because we have had too much science that the world is in a state of chronic depression? Have there been too many inventions and discoveries? Or is it that we have never learned to use the scientific scientifically? Are we, in fact, scientific in anything outside of the laboratories of natural science? How many of our modern minds that seek to keep abreast of this phenomenal multiplication of scientific knowledge have ever troubled seriously to discover what the so-called scientific method really is, how it works, and how it brings about the marvels of the "Age of Science"?

It is true that it is difficult for the layman, even if endowed with unusual intelligence, to obtain a clear picture of what even the most exact of the sciences, physics, deals with, and how it operates. On the surface there seems to be such an amazing contradiction between the magical success of the physical method, as measured by its applications, and the apparent instability of modern physical theory. In popular print physics seems to be overthrowing rather than building, yet the public continues to assume that the seemingly endless string of discoveries which the physicist turns over to the engineer and the medical man will work and work well. This diabolical trick of drawing success out of confusion is misleading, to say the least, and it may be in part responsible for the notion that the key to success in any field of endeavor lies in having a laboratory in which observations of one sort or another may be

made, in erecting imposing superstructures of conflicting and even contradicting theories and in adding the word science as a suffix. This method of beguiling the fairy, success, into a new domicile has not proved very satisfactory, and it has tended to popularize and even debase the very foundation of physical science, its methodology.

The truth is that physics is a very difficult subject, which must be understood from the ground up. The layman can, after a fashion, appreciate a symphony without knowing a thing about the technique of musical composition; but he can not well enjoy the theory of relativity without understanding much of physics, mathematics and critical philosophy. Physics works with complicated and intricate apparatus, with volumes of tabulated numbers under strange names, with still more volumes filled with innumerable mathematical symbols—all unintelligible to the interested but unequipped layman. And even when he discovers a familiar word, he is baffled to learn that it does not mean the same thing in the laboratory as on the street. So the scientific method continues to be an unsolved mystery to most laymen and philosophers, and to not a few scientists as well.

To make a difficult situation worse, some brilliant but mystical scientists have at times left the well-trodden paths of critical philosophy to venture into realms speculative and fanciful. From their fluent pens have come fascinating and romantic fairy stories to mystify the physicist and awe the layman. From their lips have come eloquent pronouncements about physics and religion, about space-time and eternity, that have been welcomed by the naive as the united voice of science and the supernatural, and hence of nature and nature's God in unison. But, as Einstein remarked, "You must distinguish between what is a literary fashion and what is a scientific pronouncement." Sir Arthur Eddington let his fancy play with a word, he expressed an opinion, it appeared in newspaper headlines, and ever since it is supposed by many that science has disproved the law of cause and effect, that it has established the freedom of the will. Notwithstanding the clear and convincing explanations by Planck, Einstein and Weyl, revealing the limited scientific meaning of the principle of indeterminacy, philosophers and preachers have continued to build castles of prejudice and desire upon an elementary misunderstanding.

In the meantime, the creative genius of pioneers like Planck, Einstein, Dirac, Heisenberg, Weyl and many others works persistently on, setting the compass for the hundreds of experiments, correlators, theorists and mathematicians who are blazing new trails or clearing and widening old ones. Mathematical-physical science is one of the truly great experiments of the human race; it is an experiment which has succeeded, not by building skyscrapers and constructing story after story upon them, but by burrowing down into the earth, digging tunnels and never hesitating to start anew, to fill in, to shovel or to blast, if that seemed desirable in finding the simplest way through that mysterious grain of the universe, the structure of nature.

II. Common Sense and Physical Science

The scientific method was not created by waving a wand. It has evolved by gradual stages from the so-called common-sense method. This, in turn, is founded upon the faculty of the human mind to receive impressions from the external world and to formulate judgments from these as to the structure of nature. It may be questioned at this early point, by those who have been convinced by the arguments of idealistic philosophers, whether there is such a thing as an external world, whether for any one individual, it is not made up

entirely of mind patterns, of ideas. However, if this contention be accepted, or even admitted for discussion, it becomes meaningless to talk about the scientific method at all. For it is precisely the object of physics to discover relations which obtain in an objective world outside of and independent of human perception and thought. Max Planck writes, "The fundamental principles and indispensable postulates of every genuinely productive science are not based upon pure logic, but on the metaphysical hypothesis that there exists an outer world which is entirely independent of ourselves." The existence of such a world is, therefore, presupposed in all that follows, together with the recognition that it is not directly knowable. Without these fundamental assumptions there would have been no science.

Before proceeding to examine the methodology of science, it is essential to examine briefly but critically the common-sense judgments of the ordinary man. These depend in the first instance upon crude perception by the senses, in particular by the eyes. No attempt will be made to discuss a theory of perception; it will be stated merely that the mind becomes aware of the outside world as a result of what are called sense-data. These are in the form of aggregates of color having a definite contour or of aggregates of sound having a definite sequence, etc. It is in searching for a cause and a comprehensive understanding of these aggregates that the mind invokes past experience as disclosed by memory. The association of successive sense impressions then leads to postulating the existence of definite objects as constituting the aggregate of repeated perception. Without enlarging upon the nature of such associations, it seems well to point out that they are not simple. Among other things they involve distinguishing between the object in question, its mirror image, a good painting or an hallucination.

The awareness of sense impressions, or memory thereof, is called a fundamental fact. Care must be exercised to distinguish between fundamental facts and inferences derived from them. Thus in the exclamation, "What a warm day!," the awareness of the individual of the sensation of hotness constitutes a fundamental fact which is not subject to further analysis or verification. On the other hand, the claim that the day is warm is an inference which may be subjected to further test, for example, with a thermometer. Fundamental facts of observation are the primary bases for ordinary or common-sense judgments. In forming such judgments, however, the individual is seldom guided alone by his awareness of certain sensations and his memory of others. Whether consciously or not, at least two other very important factors are involved. In the first place, the mind has acquired and stored in memory countless notions and ideas which are not derived directly from its own awareness, but from the accumulated judgments of other minds that have gone before it in the long evolution of the human race. In the second place, the imaginative powers of the mind are such that events which are physically meaningless or entirely impossible are readily conceived. And as a result of these, and generalizations upon them, the mind deals with innumerable subjects which are at best vaguely and extremely remotely related to direct sense-perceptions. Such are, for example, religion and mysticism which, frankly, depend not upon direct observation, but upon a mental heritage of faith and tradition.

It is clear, therefore, that the common-sense judgments of the ordinary man are composite ideas based in part upon direct observation of immediate or past experience, in part upon acquired and

unverified conceptions or upon purely imaginative associations and generalizations. The question arises, how reliable are these bases of judgment and, hence, how valuable are the judgments?

With reference to crude perception and the direct associations which depend upon it through the simple faculty of the memory, it is obvious that qualitative notions of very limited accuracy and questionable reproducibility are the best that may be expected. "The truth is," writes Whitehead, "that our sense-perceptions are extraordinarily vague and confused modes of experience." Perception depends upon relative conditions; it is limited by the shortcomings of the senses due to fatigue, nervous action or mental habits or by their innate insensibility. The eye, for example, is sensitive to only a very narrow band of electromagnetic waves and, in some individuals who are color blind, the range is still more restricted. If a drop of liquid air be placed on an individual's hand, the probability is that he will be ready to swear an oath that he has been burned by a hot liquid, simply because the sense organs are unable to distinguish between extremes of heat and cold. Optical illusions furnish a multiplicity of other examples to show how unreliable crude observations and inferences drawn from them are. Furthermore, the mind has no standard of comparison other than that furnished by memory, and this is usually vague and far from accurate, since it includes not only remembered facts of perception, but also, and in no very orderly way, accumulated judgments of other minds.

As a result of these miscellaneous accumulations in memory, the judgments of the mind are inevitably colored by personal habits of thought, by traditions of the times, by prejudices which have become parasites, by simple beliefs which are accepted on faith, by personal desires and ambitions. The human mind is not objective: It is far easier for an individual to see what he would like to see, to remember that with which he agrees or to think he understands what he hears repeated most often. Need it be said that traditions and prejudices of any kind are powerful warping influences in the forming of judgments? Thus the mind persistently seeks what it wants to find, or what it feels it ought to find. The Greeks, for example, argued that the planets must move in circles because the circle is the noblest geometrical figure. The modern mind frequently opposes the quantum theory or relativity because it feels, as a result of its limited experience, that nature should be continuous or absolute.

Unfortunately, personal prejudices about individual questions are not the only unwelcome visitors in memory's disorderly storehouse. From the beginning of science there has been a struggle between facts of observation and blind faith in an accepted authority. Religious beliefs or even unquestioning trust in the works of men like Aristotle and Newton have prevented not merely a reasonably objective association of ideas, but have definitely interfered with the correct perception of the fundamental facts of observation: Witness the distinguished professors of the University of Pisa who believed a not even correctly quoted Aristotle, rather than their own eyes, when Galileo demonstrated the laws of falling bodies. And if it is not blind faith, it is personal ambition or desire that corrupts the mind's judgments. Pope Urban VIII rejected Galileo's findings after having accepted and commended them in writing, when he was made to believe that Galileo had made fun of him. Personal vanity thus proved stronger than love of truth. The virulent nationalism of Hitler's Germany, Mussolini's Italy and Stalin's Russia represent similar situations on a large and dangerous scale in our modern times. As for America, one need but recall a recent article in *Harper's Maga-*

zine entitled, "If Industry Gave Science a Chance." The world over, wherever there is selfish ambition, the human mind believes in profit, not in truth.

Just as the mind will believe blindly and insidiously, so the imagination will construct and generalize without restraint. Carefully directed imagination and generalization are among the mind's most powerful means of discovery, but the ordinary constructs of the imagination, the fanciful extrapolations from observed facts, and the facile generalizations of the common-sense mind are among the most dangerous enemies of scientific exactitude. To use the imagination wisely presupposes a willingness, even a deep desire to discard or modify the most beautiful picture created by the mind at a moment's notice, if fact should so require.

Common sense has maintained, and millions have been ready to swear to the truth of the following statements, selected at random from the history of knowledge: (1) The earth is flat. (2) Heavy bodies fall faster than light ones. (3) A pint of alcohol and a pint of water give a quart when mixed. (4) There can be no light spot in the center of the shadow cast by an opaque sphere. (5) The velocity of light measured by an observer moving toward a source of light must be greater than that measured by a stationary observer by the amount of his own velocity relative to the light source. Each and every one of these common-sense conclusions has been proved wrong by subsequent experimental demonstration. It follows, therefore, that the common-sense basis for passing judgments is inadequate and unreliable. Seemingly obvious generalizations drawn from crude perception, modified by past experience as revealed by a memory of uncertain dependability, and as flavored by prejudice and tradition, are more often than not out of accord with the scheme of things, inconsistent with the structure of nature. To quote Millikan: "But after all, the evidence of our eyes is about the least reliable kind of evidence which we have. We are continually seeing things which do not exist, even though our habits are unimpeachable." Or, in the words of Whitehead: "The obvious common-sense notion has been entirely destroyed (by science) so far as concerns its function as the basis for all interpretation. One by one, every item has been dethroned."

The growth of science is the evolution of a means of overcoming or avoiding the limitations, the uncertainties and the ambiguities of common-sense judgments. Science has been and continues to be the development of a method for discovering the structure of nature and formulating it in a way that is simple and unfailingly true. In its quest for means by which to live in harmony with natural law, the human mind has advanced from common sense to the methodology of science.

III. The Methodology of Science

Convinced that the judgments of the unaided and untrained mind continually run counter to the true grain of things in the external world, one is led to ask modestly: What is the fundamental purpose of natural science and how does its methodology find footprints to follow in sands untouched by living feet? The man in the street never inquires beyond the first question, and its answer seems obvious to him. Is it not clear that the purpose of science must be the development of means by which man gains mastery over nature, so that he may profit from her hidden secrets and treasures? Bluntly stated, to the common man the purpose of science is a very material and practical one. Now, since the ordinary man deals entirely with things, it is only natural that his measuring stick should be that of practical value. Goethe writes: "Die Menge fragt bei einer jeden bedeutenden Erscheinung, was sie nuetze, und sie hat nicht unrecht; denn sie kann blos durch den Nutzen den Wert einer

Sache gewahr werden." But the measuring stick of physical science is not that of material things. To quote Poincaré: "Science cannot know things but only relations"; Goethe goes on to say: "Die wahren Weisen fragen, wie sich die Sache verhalte in sich selbst und zu anderen Dingen, unbekuemmert um den Nutzen, d. h. um die Anwendung auf das Bekannte und zum Leben notwendige, welche ganz andere Geister, scharfsinnige, lebenslustige, technisch geuebte und gewandte, schon finden werden." Finally, Whitehead writes: "The utmost abstractions are the true weapons with which to control our thought of concrete fact." Thus, the true aim of science should not be, and can not be, a practical one; science deals with relations unmindful of whether they have an immediate use or not. And the history of science reveals that the greatest scientific achievements have been the reward of those who have sought no practical value. To avoid misunderstanding, however, let it be noted that science in no way objects to having its discoveries put to practical use. But the very life of scientific research depends upon its not being engulfed in the emotional flux of human existence of which the patron saint is practical value and not scientific truth.

What, then, is the real aim of science? Broadly expressed, it is to discover unity in diversity. More precisely, it is to reduce the diversified quality observed in nature to coordinated and unified quantity. The pursuit of this aim involves two groups of problems. The first of these is the problem of analysis, namely, the measurement of nature's diversity, and the positivistic coordination of these measurements. The second is a problem of synthesis. It is the creation of a system of representation into which the coördinated measurements may be translated, and in which unity can be and is discovered. Before considering the solution of these two problems in turn, let it be emphasized, in the words of Planck, that "it is an indispensable postulate of all scientific research . . . , that natural phenomena invariably occur according to the rigid sequence of cause and effect."

Turning to the problem of analysis, Bertrand Russell writes, "The most essential characteristic of scientific technique is that it proceeds from experiment—not from tradition." And it is precisely by proceeding from experiment that the diversity of natural phenomena is measured. There are two kinds of experiment from which, in general, two kinds of facts are obtained. The first consists simply in observing carefully and repeatedly what happens in nature, and then having the observations verified by others. This type of experiment leads to qualitative facts. The second, and the more important type of experiment in physical science, leads to quantitative facts. These are the unique results of a very large number of highly accurate observations which are reproducible and observable by any trained observer. They are derived from refined experiments utilizing a high degree of technical skill and ingenuity. Their accuracy may be ascertained in terms of their reproducibility by applying the mathematical theory of errors.

As a consequence of this method of obtaining quantitative facts about nature in terms of operations and pointer readings, all physically real quantities, such as length, mass, force, etc., are defined in terms of the operations by which they are measured and in terms of arbitrary standards. It is an inevitable consequence of this operational mode of definition that the meanings of words such as force, length, etc., must be different from their meanings in the mouth of a layman. Physics defines those quantities which it measures directly in such a way that they have a precise physical significance as related to specific operations and to always available standards of comparison. The ambiguities of ordinary language are thus avoided.

To complete the analytical problem of measurement, physics correlates the measured quantities in the form of suitably tabulated and indexed groups. Such tabulations permit ready intercomparison of the results obtained by different observers and by different methods. In some cases it is then possible to draw positivistic conclusions which may be expressed in the form of empirical laws. Positivist philosophers often maintain that physics should stop at this point. But physics has not been convinced by their argument; it proceeds further; in fact, it jumps off into metaphysical spheres to find there its greatest triumphs.

In attempting to solve the problems of synthesis, physics has turned to mathematics. It is true that even in the solution of the problem of measurement mathematical language is used, but there it serves more the purpose of a convenient tool. In the solution of the problem of synthesis, on the other hand, mathematics is the very core of the mind's power to create. Without doubt mathematics is the greatest invention of the human mind; it is dynamic, amazingly powerful and unbelievably versatile. Those unfamiliar with higher mathematics are often inclined to believe that mathematics is nothing but a kind of glorified calculating machine or arithmetic on a grand scale. They are mistaken. In many ways mathematics is the greatest of humanities—it is a philosophy, a religion, a powerful tool, a true friend for leisure hours, if you will have it so. It need be neither cold nor dead nor matter of fact; and it is so many-sided that it finds its way into every field of knowledge. C. J. Keyser, of Columbia, writes: "The muse of mathematics is Logical Rigor, an austere goddess demanding though never quite securing absolute precision; demanding, though never quite securing absolute clearness; demanding, though never quite securing absolute cogency."

It is appropriate at this point to inquire what are the special characteristics of mathematics which make it the invaluable ally of theoretical physics in solving the problems of the structure of nature. First and foremost, mathematics deals with the understanding of relations. The properties of abstract relationships are expressed in terms of mathematical functions, and the mathematical theory of functions then provides the pattern for the study of relations and changes in relations. It will be recalled that physics is a search for relations existing in the structure of observable nature. Secondly, the mathematical theory of invariance deals with permanence, and hence serves as a framework for representing and studying forms, relations or properties which never change, but persist while all else is transformed. There must be permanence in the structure of nature, and physics must find and express it. Thirdly, and in the words of Weyl, "mathematics is the science of the infinite." Hence, it is peculiarly suited to handle such concepts as space and time, relativity and the absolute. In representing the infinite, mathematics introduces the concept of limit, and it is in terms of the mathematical limit that transcendental functions and transcendental concepts may be defined. For example, as C. J. Keyser points out, it is only with the aid of this concept of limit that a really satisfactory definition of an ideal in its most general sense may be given. Thus mathematical logic reaches out into the field of physics, but also into everyday life and thought. Specifically, mathematics might be explained to be a mental construct erected on arbitrary hypotheses in such a way that all steps leading from these to the final conclusions are logically related in terms of suitably designed symbols and operations.

The problem of theoretical physics is to translate the coordinated measurements and empirical relations obtained

by the experimental method into a pattern which may be mathematically expressed. Now, mathematical hypotheses are general and abstract statements, whereas experiment yields specific sets of values. The generalization of such sets of values is a problem of intuition and creation; its result is a physical hypothesis. This may be described as being an unproved assumption, arrived at as a result of scientific reasoning, which is believed to be partly or entirely true. It must be related to or be derived from experimental facts (or other hypotheses) in such a way that these may be deduced from it as logical consequences or results. The value of such an hypothesis is measured entirely in terms of the probability of its being true, though it is important and desirable that it be simple. Once such physical hypotheses have been conceived by a well-guided and critical imagination, they can be translated into mathematical symbols to become mathematical assumptions. Beginning with these, the stage is set for mathematics to operate independently. Before discussing how mathematics must now proceed, two matters deserve brief attention.

The first of these is the distinction between physical hypotheses and physical fictions, which it is important to bear in mind. A physical fiction is a statement which is known to be inconsistent with experimentally measured facts; a physical hypothesis, on the other hand, is believed to be in accord with these. Many physical fictions are both important and useful. Among these are mathematical abstractions such as points and lines, pictures, models, analogies and approximate solutions.

The second point deals with the possible inversion of procedure. Thus, although the primary mode of attack for the theoretical physicist is to create physical hypotheses from already available experimental data, he may imagine an hypothesis and predict from it the experimental facts required to verify it. If these facts are then found to support it, all well and good; if not, the hypothesis becomes a fiction. Actually in recent years theoretical and mathematical investigation has far outrun experimental work, since this latter is facing ever-increasing technical difficulties. It is significant to note that the mathematical method has become so powerful, and the theoretical investigators so skilful, that in most cases predictions are verified rather than disproved when the required experiments are finally performed with the usually extremely high degree of accuracy demanded. In any event, the order in which fact and theory are obtained is immaterial, so long as they finally support each other.

Let the main thread of the discussion now be resumed with a consideration of how the mathematical physicist proceeds after he has been provided with a physical hypothesis expressed in suitable mathematical language. His problem is to create a pattern to fit nature in the form of a unified mathematical representation which will satisfy all the existing hypotheses and all known facts. This is a problem in pure creation for which there is no method other than that suggested by individual intuition and genius. Before a solution of any kind is possible, however, a question of fundamental importance must be decided. The fact is that it is in general possible to represent a given set of hypotheses by a great many conceivable mathematical forms. The question is, what test is to decide which of the innumerable possible representations possesses a maximum of unity, since unity is the desired quality? The answer to this question is of primary significance; it is actually one of the basic assumptions of the entire methodology of science. It depends upon a definition, pure and simple, of what physical reality is to mean. Physical reality, and this is not to be confused with the numerous definitions of metaphysical reality provided by the several schools of phi-

losophy, is defined to be the simplest possible representation. D'Abro expresses it in the sentence, "What we call reality reduces to the simplest coordination of the facts of observation." It is interesting to note that this definition is in accord with the Greek ideal of esthetic value, though the Greeks did not, of course, require experimental verification. The justification for this definition of reality in physical science is twofold. In the first place, the definition is convenient and it is suited to the operation of the mind; in the second place, it has led to countless results consistent with the structure of nature. Evidently, then, there must exist a correspondence of some kind between simplicity, as recognized by the human mind, and what Leibniz called "preestablished harmony" in the external world. That is all that physics knows and need know to justify its method.

The solution of the entire problem of discovering unity in diversity has thus been envisaged in so far as the method pursued is concerned. Beginning with the quantitative facts of experiment, the physicist proceeds to create general physical hypotheses, to translate these into mathematical language and then to construct the simplest possible mathematical representation consistent with all available evidence. In the words of Einstein, "the supreme task of the physicist is the discovery of the most general elementary laws from which the world-picture can be deduced logically." This is the methodology of science.

IV. New Theories and Old Truths: the Evolution of Knowledge

As a consequence of the methodology just outlined, one may conclude that scientific knowledge has its inception in the accurate investigation of a great many facts, including those disclosed by carefully arranged and controlled experiments. Knowledge itself consists of unified representations of known facts from which it is possible to derive by logical steps all phenomena quantitatively and with precision.

But knowledge is never stationary so long as increasingly skilful minds, with ever more powerful experimental and mathematical tools, are finding their way deeper and further into the secrets of nature's structure. The growth of knowledge proceeds (1) from an increase in the number or the accuracy of available facts; (2) from "the creation of new mathematical constructs representing mechanisms or systems which account for facts already known and for facts discovered as a result of the new formulation."

Every new formulation, however, must win its case before the supreme and unyielding judge of all science, experiment. If it fails it becomes fiction, but may still continue to serve a useful purpose in a limited way. Such is the case with the Bohr theory of the atom and with Newton's law of universal gravitation. Any new and more general mathematical representation must include in the new form everything in the old which is verified by experiment or crude observation. Thus, the general theory of relativity must and does contain the Newtonian law of universal gravitation as a special and limiting case. Nothing which verifies Newton's law can or does disprove Einstein's; but new evidence which can not be explained in terms of Newton's law is explained and coordinated by Einstein's. Since, moreover, Einstein's law is at the same time the simplest and the most inclusive formulation which any mind has thus far conceived, and which does satisfy all available experimental evidence, it represents physical reality. It is to be noted that it is quite easy for mathematicians to prove that Einstein's equations are not the only ones consistent with the available evidence. But all alternative solutions so far suggested fall far short of Einstein's in unity, in simplicity and in mathematical elegance.

Physical reality may change from day to day; physical fact does not, except in so far as it is determined more accurately. What has been called revolution in physics is but the pulse of a gradual and persistent evolution. The methodology undergoes no radical or violent changes; it continues to be, in the words of D'Abro, "the formulation of a mental construct capable of coordinating in a simple and rational manner the sum total of our sense impressions." Experimental facts become ever more accurately known; mathematical representations become ever more general, more comprehensive, more unified. But facts remain facts, and what was once true continues true, at least during a time-span comparable with that of human history, for such is the structure of nature. New mathematical forms and new metaphysical speculations and mind pictures in no way alter the known facts about the scheme of things; they merely rearrange an understanding of these. Thus, the ancients were satisfied to let Apollo pull the sun across the heavens each day, to let Jupiter thunder his personal wrath and to let Atlas bear the world upon his shoulders while his feet rested in the "nether regions." Some moderns are still content to let a mysterious and hidden force called gravitation draw all bodies together. Meanwhile it is the aim of science to eliminate all gods, giants and hidden forces from the mind's representation of nature, and to substitute for these unified mathematical forms which coordinate symmetrically and systematically all known facts.

It would be unfortunate and incorrect to suppose that the scientific method is all-powerful and unlimited. Such is not the case. The methodology is definitely restricted by two significant factors. They are the genius of the human mind to create and comprehend, and the structure of nature itself. With regard to the first of these, the limit to the unity and generality of mathematical representation lies in the limit of the human mind to recognize unity, to encompass generality and to create mathematics. And the entire theoretical superstructure is limited by that most fundamental requirement—accurate experimental evidence. If and when the human mind can not devise means and methods for providing quantitative facts, then and there the methodology of science must fail to yield results consistent with the structure of nature. Among the limitations of the human mind is its inability to deal with several variables simultaneously. Many people think only in terms of one or two dimensions, although most are not incapable of comprehending three. When it becomes a question of a four-dimensional manifold, practically every one is completely baffled and helps himself by saying that common sense does not acknowledge the existence of such a monstrosity. But the limited value of such assertions has been demonstrated. Mathematics readily sets up problems in any number of dimensions or variables, such as some in quantum mechanics which require manifolds of several hundred dimensions. But the actual solution of problems involving many dimensions has not been accomplished in any general way.

Turning now to the limitations imposed upon science by the structure of nature, it is clear that every measurement reacts in at least a minute amount on the thing measured, and hence disturbs it. This is the core of the experimentally always verified Heisenberg principle of indeterminacy. It simply means that there must always remain a margin of doubt which no refinement in technique can ever eliminate. This margin of doubt or indeterminacy is of the order of magnitude of the smallest possible contact which can be made with the particle or quantity to be measured. Clearly such a contact involves the smallest package of energy which exists. Since this is of a definite, though ex-

tremely minute size, there is no way of reducing this smallest contact below a certain minimum. A single quantum of energy is so small that it plays no part whatsoever in determining the accuracy of macroscopic measurements dealing with large bodies and large quantities of energy. In microscopic measurements, on the other hand, such as the measurement of the position or the velocity of an electron, a single energy quantum is relatively so large that the margin of doubt in the measurement becomes extremely great. It is clear that the structure of nature thus definitely limits the experimental physicist in his microscopic measurements. The conclusion that, because nature does not provide infinitely divisible packages of energy, it is chaotic and not governed by cause and effect, is certainly not required by any scientific evidence. In fact, it is completely beyond the realm of scientific inquiry to draw such a conclusion. To extrapolate still further, and to affirm that science proves anything about the freedom of the human will, is absurd. The awareness of an individual of whether his will feels free or determined is entirely outside the field of application of scientific methodology at the present time.

The fact that physical science has advanced by leaps and bounds is sufficient evidence to suggest that its limitations have not as yet proved a serious handicap. The mind grows as it creates, and what may be an insurmountable obstacle in its path at a given stage of development may be overcome by a succeeding generation of scientists. On the other hand, the recognition and the discovery by physics of such fundamental limitations as that stated by the principle of indeterminacy are achievements of the first rank. It is real knowledge to know that there can be no perpetual motion and that there is a definite limit to experimental measurement of microscopic phenomena. Such discoveries are signposts that reveal that the structure of nature is not uniformly putty-like. It is between such guiding beacons that science must continue to feel its way into the fathomless unknown. Shortly before his death Newton wrote: "I do not know what I may appear to the world, but to myself I seem to have been only a boy playing by the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay undiscovered before me."

In a brief conclusion, it may be said that the methodology of science is the only consistently successful method the human mind has discovered to learn something about the true structure of nature. And it is only with the aid of such knowledge that a groping mind can adjust itself to harmony with natural laws in the most general sense. The modern mind might well strive to realize, as Newton's did, that its judgments are like answers to the question, How many stars are in the sky? and that its enlightenment is like that of a man exploring the universe in a starless night with a single match. To be sure, science itself is but a new-born child in the great march of the centuries, and its future is unpredictable. But perhaps the time will yet come when a maturer science will lead a saner world to harmony with the scheme of things in all rational fields of human endeavor and thought. And if it does, then there will have echoed through countless centuries the words of Lord Kelvin: "When you can measure what you are speaking about, and can express it in numbers, you know something about it, and when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thought advanced to the stage of science."

SUNLIGHT AND HEALTH

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The number of abnormal conditions primarily and specifically benefited by sunlight, natural or artificial, is small in comparison with the number for which such claims are made. Sunlight constitutes one of the benefits of an outdoor life; it is one of the elements of climate that make for physical and mental well-being; in extrapulmonary tuberculosis, when judiciously used, it aids and promotes healing; in rickets, certain wave-lengths are specific; but these facts do not justify the extravagant claims made for it as a vitally necessary curative and preventive agency. Certain diseases and disabilities are partly due to deficient radiation, and doubtless the health of the community may be improved by providing more artificial radiation where sunlight does not reach the small minimum required for health; but sunlight is only one of the many environmental factors that influence health. Climate in its relationship to health is not merely a question of sunlight, but of fresh air, wind, temperature, humidity, altitude above sea level, etc., as well. "Heliotherapy" includes all these, as well as diet and occupation. Sunlight is of paramount importance to plants, but of secondary importance to animals. Because a certain portion of the solar spectrum is specific in preventing and curing rickets, and exposure to sunlight promotes the healing of certain manifestations of tuberculosis, does not imply that every one is suffering from a lack of sunlight. Sunlight plays a subordinate part in the regulation of the physical and chemical processes that make up the life of normal man, who can get along with little or practically none of it, provided his diet be adequate and that he take care of himself in the way of getting plenty of fresh air, sleep and exercise.

All sunlight is not *light,* which is that agent, force or action in nature by the operation of which on the organs of sight objects are rendered visible or luminous. Light is visible radiant energy. When sunlight is passed through a prism it is broken up into its constituent parts, it is dispersed, and if the dispersed rays are focussed on a screen they form a spectrum with the red rays at one end and the violet at the other (see Fig. 1). These rays have definite wave-length, extending approximately from 400 millimicrons at the violet end to 800 millimicrons at the red. There is an octave, so to say, of visible spectrum. To either side of these visible wave-lengths of radiant energy there is invisible radiant energy. On the violet side there is the "ultra-violet," extending in sunlight to about 300 millimicrons, shorter wave-lengths being detectable only under conditions of exceptional atmospheric purity. At the red end there is the "infra-red," extending in sunlight for all practical purposes to 3 microns (3,000 millimicrons), only 1 per cent. of the total solar spectrum being found at wave-lengths longer than this. The total amount of ultra-violet radiation shorter than 310 millimicrons is extremely small, usually only from 0.01 to 0.1 of 1 per cent. and not more than 0.2 of 1 per cent. of the total on the clearest days at noon in summer at sea level at mid-latitude.

Although these invisible ultra-violet and infra-red rays or wave-lengths are certainly not light, being invisible or non-luminous, they are, more often than

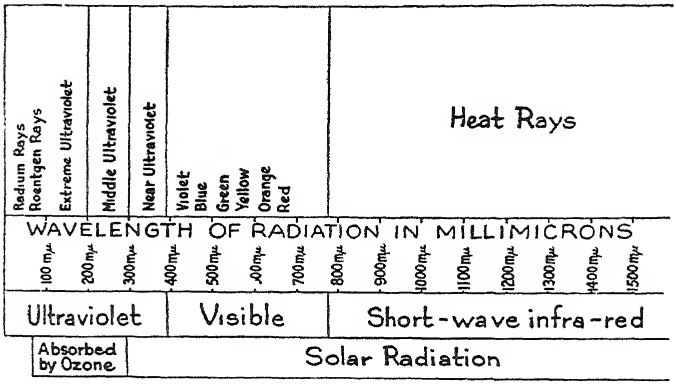


FIG. 1. THE CONSTITUENT PARTS OF THE SPECTRUM OF RADIANT ENERGY.[1]

not, included in the implication of that word. In this sense light has come to include not only visible energy (light, *in sensu strictu*) but also ultra-violet and infra-red energy. Usage, even when fundamentally incorrect, is difficult, if not impossible, to combat.

Sunlight is our natural source of "light" for treatment. In many places, however, its intensity varies too much or is too weak for too great a proportion of the time to permit of its being a practical source. As artificial sources the mercury vapor arc in quartz, the flaming carbon arc and "heat" radiators are the only ones of practical importance. The penetrating long-waved luminous and short-waved infra-red rays emitted by tungsten lamps (200–500 watt) and by parlor or bathroom electric heaters are of value in conditions requiring deep action, in the relief of deep-seated pain, as in sprains, fractures, pulled tendons, bruised muscle, etc. The energy emitted by the quartz mercury arc and the carbon arc extends farther into the ultra-violet and infra-red regions than does the energy of sunlight. The flaming carbon arc extends from 218 millimicrons to about 6 microns, while the energy emitted by a quartz mercury lamp begins at 185 millimicrons and ends in the long infra-red.

At the surface of the earth, with the sun moderately high and a total intensity between 1 and 1.5 gm. cal. per sq. cm. per min. (70,000 and 105,000 microwatts per sq. cm.), the percentage of the energy that is ultra-violet is between 1 and 5, luminous between 41 and 45 and infra-red between 52 and 60. When the sun is lower and the total intensity less, the ultra-violet is relatively decreased and the infra-red increased. At high altitudes above sea level the total energy is increased and with this the percentage of ultra-violet, while that of the infra-red is diminished.

The radiation from the flaming carbon arc is the closest approximation to natural sunshine. In one of our lamps with 25 amperes flowing through the arc, burning sunshine carbons, the total energy emitted is 0.325 gm. cal. per sq. cm. per min. incident at a meter, or 1 gm. cal. at 57 cms., and 1.5 gm. cal. at 46.6 cms., with a distribution of 6 per cent. ultra-violet, 50 per cent. luminous and 44 per cent. infra-red. With a Corex D screen, which eliminates by absorption the ultra-violet and infra-red rays not found in sunlight, the total energy emitted is 0.287 gm. cal. incident at a meter, or 1 gm. cal.

[1] This diagram is adapted from one appearing on page 12 of "Light and Health," by M. Luckiesh and A. J. Pacini, published by the Williams and Wilkins Company.

at 53 cms., and 1.5 gm. cal. at 43.4 cms., and its distribution is 5 per cent. ultra-violet, 63 per cent. luminous and 32 per cent. infra-red.

A larger percentage of ultra-violet can be obtained by using other carbons, *e.g.*, the "Therapeutic C" carbon. When these are burned, no glass screen being used, the total energy emitted has the same value as the "sunshine" carbons, but the distribution is 9 per cent. ultra-violet, 24 per cent. luminous and 67 per cent. infra-red. Mercury lamps have quite different distribution spectra from these values, for instance, a new mercury lamp (4 to 5 amps., 70 to 80 volts), emits 28 per cent. in the ultra-violet, 20 per cent. in the luminous and 52 per cent. in the infra-red; and an old mercury lamp in our laboratory has a distribution as follows: 13 per cent. ultra-violet, 7 per cent. luminous and 80 per cent. infra-red. The total energy emitted is much lower than in the carbon arc and in sunlight (about 0.06 gm. cal. per sq. cm. per min. incident at a meter) in agreement with the lower power input.

The almost immediate reddening of the skin on exposure to sunlight or to a flaming carbon arc is due to radiant heat (infra-red and long luminous) rays. It is followed in a few hours by the erythema or "burn" due to the action of the ultra-violet rays. An artificial source must emit a certain minimum amount of ultra-violet in order to insure effective therapeutic action when such wave-lengths are indicated. The amount of ultra-violet radiation that can be applied to the body without producing a burn depends on the tolerance of the skin, which can be measured by the erythema or burn produced, specifically a mild or "minimum perceptible erythema," one that disappears in the course of twenty-four hours. This reaction is produced by wave-lengths shorter than 315 millimicrons. The midday, mid-latitude, sea-level ultra-violet shorter than and including 313 millimicrons in summer sunshine with an intensity of from 80 to 90 microwatts per sq. cm. produces a minimum perceptible erythema in from 20 to 45 minutes, depending on the person. In winter when the intensity is only about 20 microwatts (on the clearest days at noon) the time is lengthened to from 3 to 5 hours. Forenoon and afternoon summer sunlight has an average intensity of 30 microwatts per sq. cm. Judged by the erythemal response the intensity of wave-lengths less than and including 313 millimicrons emitted by an artificial source should not be less than 20 microwatts (Coblentz).

There is no close relationship between the spectral erythemic response and the general therapeutic or curative action of radiant energy, but the erythemal reaction is taken as a criterion for judging the effectiveness of a lamp for three reasons: (a) It is practically the only physiologic reaction that is established with a relatively high degree of accuracy; (b) it is a simple and practical means of preventing severe burns, and (c) it is an efficient safeguard against the sale of lamps that are deficient in ultra-violet radiation. The effective ultra-violet emitted by the present-day "professional models" of the various kinds of therapeutic lamps greatly exceeds the specific minimum value of 20 microwatts.

The Influence of Sunlight on the Skin

The skin is not simply a protection but an organ with nervous, nutritional, circulatory and excretory functions. Its exposure to radiant energy improves its blood supply with consequent improved nutrition and removal of waste. It is the organ most immediately and intimately acted upon by "climate." A toneless and inelastic skin, white with yellowish tinge tending to grayish and quite dry,

LAYER	λ mm	200	250	280	300	400	550	750	1000	(1400)	mμ
		100	100	100	100	100	100	100	100	100	APPLIED
CORNEUM	03	100	81	85	66	20	13	22	29	56	ABSORBED AND REFLECTED
		0	19	15	34	80	87	78	71	44	TRANSMITTED
+MALPIGHII	05	0	8	6	18	23	10	13	6	16	ABSORBED
		0	11	9	16	57	77	65	65	28	TRANSMITTED
+CORIUM	20	0	11	9	16	56	72	44	48	20	ABSORBED
		0	0	0	0	1	5	21	17	8	TRANSMITTED
+SUBCUTAN	25	0	0	0	0	1	5	20	17	8	ABSORBED
		0	0	0	0	0	0	1	0	0	TRANSMITTED
		EXTREME U VIOL	FAR ULTRA VIOLET		NEAR U. VIOL.	VISIBLE VIOL. GREEN RED		NEAR INFRA RED		FAR INF RED	
GENERAL REMARKS		All absorbed by corneum. No radiation reaching germinativum	Greatest absorption in stratum corneum. Some radiation reaches corium (papillare). No radiation reaches subcutaneous layers		Relatively large absorption in stratum Malpighii.	Minimum absorption in stratum corneum. Most radiation absorbed in corium. Pronounced radiation reaching subcutaneous layers		Strongly increasing absorption in upper layers, decreasing in lower layers.		Practically no penetration.	

FIG. 2. ENERGY DISTRIBUTION IN THE LAYERS OF THE SKIN. THE NUMBER 100 DESIGNATES THE APPLIED INTENSITY. THE ENCIRCLED NUMBERS REPRESENT PERCENTAGES ABSORBED IN EACH LAYER. THE NUMBERS IN THE NARROW ZONES BETWEEN LAYERS REPRESENT THE PERCENTAGES OF THE ORIGINAL INTENSITIES TRANSMITTED THROUGH THE LAYER ABOVE. (BACHEM AND REED.)

may, after 3 to 4 weeks' stay at the seashore, appear entirely changed, and not only that portion which is exposed to the sun and therefore tanned, but the unpigmented, covered skin, which becomes pink, soft, smooth and elastic. The color of the skin, to a certain extent, serves as an index of the state of well-being and has been interpreted as evidence of health or disease.

The skin reflects and transmits different parts of the spectrum quite differently, and different parts of the body behave differently. Pigment, hair and blood are important elements in determining the relative amount of the energy absorbed. Fig. 2 shows the relative penetration of important wave-lengths between 200 and 1,400 millimicrons, as determined by Bachem and Reed. The blood which flows through the skin is of great importance. The more the capillaries are filled, so much the more the shorter rays will be taken up by the blood and given up to the organism as a whole, and so much the more the long-waved energy will pass through the network of blood vessels and penetrate to the deeper layers of the body.

Erythema and Pigmentation: As above mentioned the almost immediate reddening of the skin after irradiation with energy containing ultra-violet, luminous and infra-red rays is due to radiant heat (short infra-red and long luminous rays). This heat reddening frequently has a mottled appearance and is not restricted to the irradiated parts of the skin and disappears soon after the irradiation is stopped. It is followed in a few hours by a "burn" due to the action of the ultra-violet rays. The usually diffuse and homogeneous redness of this "burn" is confined strictly to the irradiated part and, according to the intensity of the radiation, may be combined with

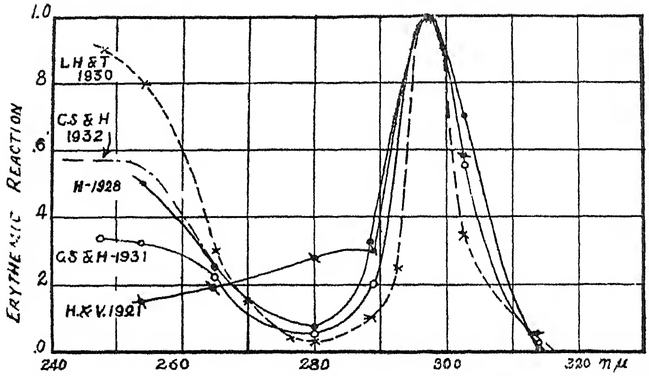


FIG. 3. RELATIVE SPECTRAL ERYTHEMIC REACTION OF THE HUMAN SKIN TO EQUAL AMOUNTS OF RADIANT ENERGY AT VARIOUS WAVE-LENGTHS AS DETERMINED BY SEVERAL INVESTIGATORS. (COBLENTZ, STAIR AND HOGUE.)

blistering and hemorrhage. The inflammation lasts for some time, to be followed by peeling and pigmentation. "Sunburn" and the inflammation or "burn" caused by carbon and other arcs is one and the same thing. As Fig. 3 shows, the wave-length range of the rays producing sunburn begins at about 315 millimicrons and extends to an undetermined wave-length shorter than 240. The erythemic response curve rises steeply to a maximum at 297, descends to a minimum at 280 and then rises to a less intense maximum in the region of 250.

Ellinger has studied the ultra-violet erythemal reaction of many hundreds of subjects and reports great variability in the sensitivity of different individuals. Blondes are much more sensitive (40–170 per cent.) than brunettes, and women less sensitive (20 per cent.) than men. All persons under 20 and over 50 have a lowered sensitivity. There is a maximum sensitivity in March and April and again in October and November (see Fig. 4). Persons with an unstable nervous system, an overactive thyroid gland or with high blood pressure or active tuberculosis also show a quite high sensitivity.

The observations of Sir Thomas Lewis show that in all types of skin injury the vascular response is brought about by the action of a chemical substance liberated in the tissue spaces as a result of the injury. This hypothetical diffusible substance is a histamine-like substance or even histamine itself and is called H-substance. According to Ellinger, the thyroid gland is primarily responsible for the increased sensitivity and there is a relation between the number of open, that is functioning, skin capillaries per surface area and the light sensitivity. If the activity of the thyroid gland is increased the metabolic rate is increased and the body temperature shows a tendency to rise. In order to prevent this, that is to say, in the interests of the regulation of the body temperature, there is an increase in the number of open, functioning capillaries in the skin, which increases, *pari passu,* the sensitivity to the erythema-producing ultra-violet rays.

Function of Pigment: The essential function of the skin pigment, melanin, has for long been thought to be the protection it affords the organism against excessive irradiation. Every one has observed how the skin of persons accustomed to an outdoor life, and thus tanned or pigmented to a greater or less degree,

does not react on exposure to strong sunlight, which acts painfully on the unaccustomed, unpigmented skin of others.

Ectodermal pigment is found in the epidermis, almost exclusively in the basal cells, chiefly in characteristic cap form over the distal pole of the nucleus, but also in branched cells (Fig. 5, p. 323). The other living cells of the epidermis and the horny layers in the white race contain pigment in considerable amount only when pigmentation is extreme. In Negroes not only is pigment more abundant in the basal layer, but there is also much pigment in the outer, including even the horny, layers. The mesodermal pigment is in the corium, or cutis vera, and does not interest us here.

Considerable evidence has been recently brought against this view, first clearly expressed by Finsen and quite universally held since his day, that a pigmented skin was protected against excessive damage by ultra-violet rays shorter than 315 millimicrons. The "modern point of view" concerning the protective function of the skin against ultra-violet is as follows. The shorter-waved rays are absorbed superficially in the horny layer (about 30 millimicrons thick), and thus never reach the living cells of the epidermis. *The horny layer is the screen for the epidermis against the shorter ultra-violet rays.* The longer-waved ultra-violet which penetrates as far as the true skin (thus at least 50 millimicrons) may act on the blood in the capillary vessels of the true skin. The basal layer pigment, which increases after irradiation with ultra-violet shorter than 315 millimicrons, regulates the amount of this longer-waved energy, which reaches and penetrates the basal cells and thus protects the underlying true skin from receiving too much energy. *Pigment is the screen for the true skin against the longer ultra-violet rays.*

Quite a number of authors believe that this pigment absorbs the luminous and short infra-red rays so that the heat effect is localized at the surface, from which it may thus be more readily lost, so protecting the body as a whole from overheating. The advantage enjoyed by dark-skinned persons over fairer ones in a hot climate in the way of greater tolerance to the rays of the sun is thus plausibly assumed to be demonstrated. The Negro's skin heats sooner and to a greater extent than does that of the white man; he therefore sweats more copiously and, what is also of importance, the sweat evaporates more quickly, owing to the higher temperature of the skin. All this, however, while plausible, is almost all assumption, and what accurate work has been done to demonstrate it has failed. Briefly, we may say that pigment absorbs, to varying degrees, all the wave-lengths of sunlight. Its protective function is but slight in white-skinned persons, more important in dark-skinned races, particularly for the ultra-violet rays. The increased absorption of penetrating heat rays does not appear to give the Negro any advantage over the white man in regulating his body temperature.

Therapeutic Value of Pigment: There

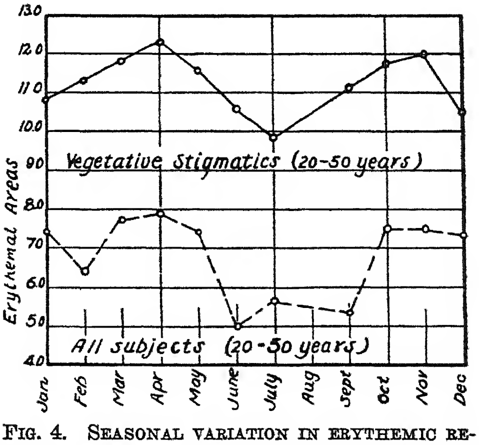


FIG. 4. SEASONAL VARIATION IN ERYTHEMIC REACTION IN NORMALS AND IN THOSE WITH AN UNSTABLE NERVOUS SYSTEM. (ELLINGER.)

is no unanimity of opinion. Many regard pigment, owing to its absorption, as unfavorable for the action of "light" and therefore attempt to prevent its formation. Others ascribe to it a very important value and believe that the degree of pigmentation is a favorable diagnostic sign, brunettes thus responding better to insolation than blondes.

A logical statement, in view of the evidence at hand, is that pigment formation and healing, or benefit from the energy, seem to represent independent, coordinate phenomena proceeding simultaneously in the same direction. Since the horny layer is a more important protector against over-irradiation by shorter ultra-violet rays than is the skin pigment, there is left but one outstanding significant connection between radiation and pigment, namely, as an indicator of the action of the radiant energy, its intensity being, to a certain extent, proportional to the amount of action. But it is also very dependent upon individual factors such as race, constitution and body function. Pigment formation is an indicator of the wished-for action and can be used as a measuring rod for treatment and, since pigment formation, horny layer thickening and possible chemical alterations of the skin cell proteins run practically parallel, it is also a measure of adaptation or of lowered sensitivity.

The Effect of Radiant Energy on Wounds and on Some Skin Diseases: Natural sunlight will hasten the healing of sluggish, indolent wounds, as was demonstrated so clearly in 1902 by Oscar Bernhard at Samaden, Switzerland. The effect, however, is certainly not specific to the short ultra-violet rays but brought about by wave-lengths that penetrate through the epidermis and part of the dermis, producing their action indirectly through the circulation. The surface action of ultra-violet wave-lengths shorter than 315 millimicrons in large quantity is detrimental to the healing of wounds, unfavorably influencing the processes of repair. The beneficial influence is due to longer ultra-violet, luminous and short infra-red rays.

Until Finsen, by means of strong carbon arc radiation, cured so many cases of tuberculosis of the skin (about 60 per cent. of those he treated) the disease had been regarded as almost incurable. Reyn has found that local treatment combined with general exposure is beneficial in approximately 90 per cent. of cases. The result of the treatment depends, as in the treatment of wounds, upon the depth of the action of the effective rays, and, in selecting the source, the one with the maximum penetration of these rays must be chosen, namely, the flaming carbon arc lamp.

Tuberculosis of the skin (*lupus vulgaris*) seems to be the only skin disease on which ultra-violet rays act specifically as a result of direct action or indirectly through general body irradiation. Of skin diseases for which claims are made for the beneficial action of sunlight and artificial radiation the following may be mentioned: dry and weeping eczema, pruritus, local and generalized urticaria, psoriasis, *acne vulgaris,* varicose ulcers with associated dermatitis, vascular nevi, *alopecia areata* and the loss of hair following severe infections, but the improvement that may follow is not a specific effect. In some cutaneous disorders (eczema, urticaria, psoriasis, *lupus erythematosus, herpes simplex, xeroderma pigmentosum,* farmer's skin, prematurely senile skin) exposure to such rays may cause a flare-up or provoke an attack.

Influence of Sunlight on the Blood and Circulation

The influence of sunlight on the blood may be passed over briefly, since, while radiant energy, including longer ultra-

violet, luminous and infra-red rays, such as natural sunlight and its close approximation—the energy emitted by "Sunshine" carbons—may have some effect on secondary anemia, this is limited, not specific, and merely adjuvant to established dietetic and drug treatment. Irradiation of this sort may also be used in cases of diminished platelet count, as in some instances of *purpura hemorrhagica* (idiopathic). We have seen one very significant case in our laboratory in which a 5-year-old boy, refractory to all other treatment and for whom removal of the spleen had been advised, was given 7 graded carbon arc irradiations over a period of two weeks, with an increase in the platelet count from 45,000 to 400,000, at which high level it remained for 3 months when the patient was dismissed. The boy has been now symptom-free for four years.

Ultra-violet rays alone do not lower blood pressure, but carbon arc radiation ("Sunshine" or "Therapeutic C" carbons) does—that is to say, of a certain percentage (from 60 to 70) of persons with abnormally high blood pressure. I have shown in both ambulatory and hospitalized patients with essential hypertension that both systolic and diastolic pressure may be materially reduced (from 10 to 15 per cent.) by general carbon arc irradiation. The "cure" is temporary, and the treatments have to be repeated, being given every ten days or two weeks in those whose pressures have been lowered by earlier more often repeated large doses (usually every fourth or fifth day). The individual doses must be large enough to set up an inflammatory reaction, accompanied by marked vasodilatation, not too frequently repeated, so as to avoid adaptation.

The amount of blood ejected by the heart per minute (the cardiac output) shows a significant tendency to increase when the blood pressure is lowered by carbon arc irradiation. This may be a compensatory reaction secondary to the dilation of the blood vessels and the drop in blood pressure.

The Influence of Sunlight on Mineral Metabolism

Rickets: Ultra-violet rays shorter than in rectifying the partial lack of the 313 millimicrons are of great importance dietetic components necessary for building bone. The process of irradiating a baby with such ultra-violet wave-lengths consists in giving rise to vitamin D from the provitamin in the skin. The irradiation influences the formation of vitamin D and the storage of calcium and phosphorus and the equilibrium of these elements in the blood stream of mature animals in a way similar to the effects upon growing animals, and the antirachitic factor represents specifically the organic agent which promotes normal calcium anabolism. It may prevent and cure rickets, it may promote growth, or it may simply prevent excessive loss of lime from the body. The specific capacity in which it functions depends upon the condition of the animal, both with respect to age and nutrition, and upon the composition of the diet. Radiant energy simply revives, or aids, a depressed function. The antirachitic vitamin D is prepotent in preventing rickets, and is capable of doing so in the entire absence of sunlight. Ultra-violet radiation may rectify partial but not absolute lack of the dietetic components necessary for bone and teeth calcification. Ultraviolet rays of wave-length 313 millimicrons and shorter and vitamin D cause the organism to operate more economically, they make metabolism more efficient, they permit the organism to have full use of normal processes which are not effective, but they do not bring new processes into operation. Ultra-violet plus luminous and infra-red radiation does

not favorably influence the union of fractures.

Teeth: Diet influences the formation of teeth by virtue of vitamin D, which increases and controls the actual calcifying process and by containing sufficient calcium and phosphorus. The vitamin seems necessary not only for the original development of the tooth but for its protection later in life. In dental caries, rickets seems to be merely one of several etiologic factors. Dental caries is not the result of low calcium or low phosphorus content of the blood. A comparative study of enamel, dentin and bone in newborn and very young infants shows quite clearly that the formation of enamel and that of dentin in the unerupted teeth do not parallel each other but that those of bone and dentin do. Enamel is an epithelial tissue arising in the ectodermal layer of the embryo, while bone and dentin are connective tissues originating in the mesoderm. This may be why the teeth of children with marked stigmas of rickets are often well formed and free from decay, and why tooth decay may be rampant in rapidly growing, breast-fed infants in the tropics, with no evidence of rickets.

Milk in Rickets: As human milk or that of some animal forms the almost universal diet of infancy, it has been surprising to learn that rickets can occur so frequently. One expects milk above all foods to embody the essentials for good health and development during infancy. But milk is poor in the antirachitic factor, vitamin D, of which even the highly prized human milk contains only a small amount. Consequently any high protective value of human milk in infantile rickets can not be ascribed to its content of the antirachitic factor.

Since the introduction of irradiated ergosterol and irradiated foods for the prevention and treatment of rickets, several methods have been satisfactorily employed to impart anti-rachitic properties to milk, such as (1) the irradiation of milk in powdered, evaporated and liquid form; (2) the irradiation of the mother or of the wetnurse; (3) feeding to the cow irradiated yeast, and to the woman cod liver oil or irradiated yeast; (4) adding irradiated ergosterol (yeast) to the milk; (5) adding to the milk a vitamin D concentrate prepared from cod liver oil.

Infantile Tetany: Infantile tetany is a symptom complex which occurs in rickets when the salt equilibrium in the blood happens to be of a kind which sets the nervous system in a state of hyperexcitability, namely, low calcium, and it is with the low calcium form of rickets that manifest tetany is associated. Any agent capable of raising the calcium concentration to a level within 20 per cent. of the normal will cure the active manifestations of tetany. The treatment of choice is a combination of some salt of calcium and irradiated ergosterol (viosterol).

Activation

The independent and almost simultaneous demonstration in 1924 by Hess and by Steenbock and Black that certain substances, inert in so far as calcifying and growth-promoting power are concerned, may have these capabilities bestowed upon them by irradiation has proven to be of far-reaching importance. The facts that when an animal is irradiated its skin, liver and muscle become antirachitically active, and that eggs and milk have increased or newly endowed calcifying and growth-promoting powers bestowed upon them; and that foodstuffs deficient in the antirachitic vitamin may have it supplied to them by judicious irradiation, have proven not only of interest and of therapeutic value, but have done much toward clarifying our conception as to the mode of action of sunlight and of vitamin D in the prevention and cure of

rickets. Ultra-violet radiation forms vitamin D either in the cells of the living creature or in its foodstuffs. The action of a foodstuff artificially rendered antirachitic by irradiation is identical with the action of a naturally occurring foodstuff containing the antirachitic factor.

The use of irradiated milk (fluid, dried, evaporated or condensed) is proving to be one of the important prophylactic developments of "activation." Of less importance is the activation of other foodstuffs (cereals, bread, etc.). A fact of broader interest than the prophylactic and curative value of irradiated milk is the clear demonstration of the superior clinical effectiveness of irradiated milk to cod liver oil and to viosterol (irradiated ergosterol) as well as to the milk from cows fed irradiated yeast. It would seem that the effect of irradiating milk with ultra-violet rays is to produce a substance of peculiar efficacy in the treatment of human rickets. Perhaps the combination of pro-vitamin D with the milk proteins may enhance the usual effect of irradiation on this sterol.

Photodynamic or Optical Sensitization (Harmful Effects of Sunlight)

It is possible to sensitize living cells, just as one sensitizes a photographic plate, and produce an abnormal condition in which luminous rays are as active as ultra-violet. This is photodynamic or optical sensitization. Most of the substances which act as sensitizers are fluorescent, but photodynamic action is not proportional to the degree of fluorescence, and while fluorescence is the usual accompaniment it is not the fundamental cause of the sensitization. The presence of oxygen is necessary for most of the effects produced by light, and the wavelengths which are effective are those absorbed by the sensitizer.

Photodynamic sensitizers arising under physiological as well as pathological conditions are capable, in the presence of light, of destroying both warm- and cold-blooded animals. There are illnesses which affect man and animals when they are exposed to light, either because the light is very strong or on account of increased sensibility, owing to the presence of a sensitizer or sensitizers. These may be exogenous, getting into the organism with the food, or endogenous, produced by the organism itself. Life can be wiped out by light and has been observed in organisms from man to the lowest.

The usual meaning attached to photodynamic sensitization is the production by luminous rays plus a sensitizer of the same reaction that ordinarily takes place under ultra-violet. A very considerable difference, however, exists; whereas the ultra-violet effects can occur either in the presence or absence of molecular oxygen, the photodynamic effects occur only in the presence of oxygen. Sensitization, however, may also be induced in the ultra-violet.

Pathologic conditions produced by sensitization in lower animals are the buckwheat sickness in cattle, the condition seen in sheep after eating St. John's wort and the clover sickness of horses and cattle.

Amongst conditions found in man presumably or possibly due to endogenous sensitization are the following: *hydroa estivale* or *vacciniforme, eczema solare, prurigo estivale* or summer prurigo, *xeroderma pigmentosum, urticaria solaris,* sailor's or farmer's skin, skin cancer, *lupus erythematodes discoides.*

Prolonged exposure to the violet and ultra-violet rays of sunlight or of artificial sources may cause not only systemic disturbances but also inflammatory and degenerative changes in the skin, varying with the person. The harmful systemic effects have not been well understood, but

deaths of infants following short exposures to ultra-violet radiation have been reported (Greenbaum). Hausmann also sounds a warning against the dangers of overindulgence in radiation. He believes that nowadays there is little danger that people on the whole are getting too little sunshine, but rather that they get too much, and that this is going to give rise to a number of acute and chronic pathologic conditions, if these are not present already. He is convinced that the central nervous system, especially the brain, must be injured by the over-irradiation and resultant heating of the skull. Furthermore, although the skin may become accustomed to sunlight, its action on certain parts of the skin results in a predisposition to certain conditions. An outstanding example is the well-known reddening of the chest of women, designated by Brocq as "*Dermatose du triangle sternoclaviculaire.*" This conditions a *locus minoris resistentiae* for several skin diseases, such as acne, urticaria and eczema, which, if not due directly to the action of light, are indirectly so. Klare has called attention to a febrile bronchitis manifesting itself in some children, usually of light complexion with hair of a slight reddish tone. The skin reacts with inflammation and burning, not with pigment formation.

The Action of Sunlight on Tuberculosis

Heliotherapy has enjoyed two triumphs—the cure and prevention of rickets and its action as an auxiliary in the treatment of extrapulmonary tuberculosis—but there are numerous points in the latter which are far from settled. The results obtained, especially in bone tuberculosis, by a treatment régime, in which heliotherapy in the form of the complete sun bath is one of the factors employed, are impressive. But, while heliotherapy undoubtedly plays a large part in the results it is only a part, not the whole, of the régime. It is at present impossible to evaluate the other factors such as: exposure to dry and pure air, freedom from fog, dust, winds and rain, combined with ideal conditions of feeding, prolonged periods of rest, orthopedic treatment and, wherever possible, pleasant occupational therapy. These, in themselves, must play a large part in the excellent clinical results obtained.

Numerous contra-indications have been advanced to heliotherapy in phthisis, but the only valid one is met with in all localizations of the disease. When a patient is very weak, with much toxemia and hectic fever, the sun bath is liable to do more harm than good, and should therefore be deferred with the hope that rest and fresh air will strengthen the patient sufficiently for insolation to be justifiable at a later date. The combination of hot air and sun is bad for any form of tuberculosis, though particularly dangerous in the pulmonary variety.

For the extrapulmonary forms of tuberculosis physicotherapeutic measures often prove valuable adjuvants, but they are never to be employed to the exclusion of rest and hygienic-dietetic, and perhaps surgical, measures. Light in any form by itself is not curative but may prove an important aid. To believe that light by itself will cure tuberculosis, to be unduly optimistic about its effects and consider it a specific form of treatment, or to use it without sound medical advice and employ it to the exclusion of rest, hygiene and diet, eliminating orthopedic measures or the occasional necessary surgical intervention in bone and joint tuberculosis, is bound to bring criticism to an otherwise eminently desirable method of treatment. —*Mayer.*

The dangers of heliotherapy to be uninitiated tuberculid should not be treated lightly.

The sun is a powerful agent, and as a therapeutic instrument it is powerful for good, now widely known, but it is equally, or in even a greater degree, powerful for harm which is not so generally understood. For much of the abuse

of heliotherapy physicians have no direct responsibility. The idea that sunlight will cure tuberculosis is one admirably adapted to win popular acceptance, since it fits in so perfectly with well known facts, and is in itself so immensely attractive Nearly everybody has heard of the idea, or known some one else who has heard of it, so that it is hardly in the least surprising that a man who finds himself infected with the disease should begin at once to bare himself to the sun Many persons are doing it to-day, without the advice of a physician, with no knowledge as to whether it is indicated in the particular case, or as to how, if it were indicated, it should be gone about A man with a violent infection in both lungs will think nothing of exposing the entire surface of his body, the chest included, to a combination of bright sun and hot, humid air The result is that an alarming number of patients, under the influence of misinformation or incomplete information, are in this way jeopardizing their lives or even putting themselves definitely beyond the hope of cure But the abuse of heliotherapy is not confined to the lay public Within the limits of the medical profession the subject is not so generally or so fully understood as it ought to be This fact is not surprising; indeed, it may be readily explained. Comparatively few physicians have occasion to make use of heliotherapy in their practice, and those who do not, having no special incentive to acquaint themselves with the treatment, are likely to entertain wrong notions regarding it not greatly different from those entertained by persons outside the profession —*Watson.*

Many specialists feel that heliotherapy constitutes a valuable aid to the fresh air cure in the treatment of pulmonary tuberculosis; furthermore, that it can be practiced everywhere, particularly favorably at the seashore or mountains, but best carried out in the climate most suitable to each individual case. On the other hand, many feel that its results are "not likely to be spectacular and its omission not detrimental to the patient's best interest" (Laird)

Conclusion

The number of human ills and abnormalities for which radiant energy, as emitted by the sun, carbon arcs and quartz mercury vapor lamps, is specific or adjuvant is small, much smaller than the number for which claims are made by manufacturers of lamps as well as by members of the medical profession.

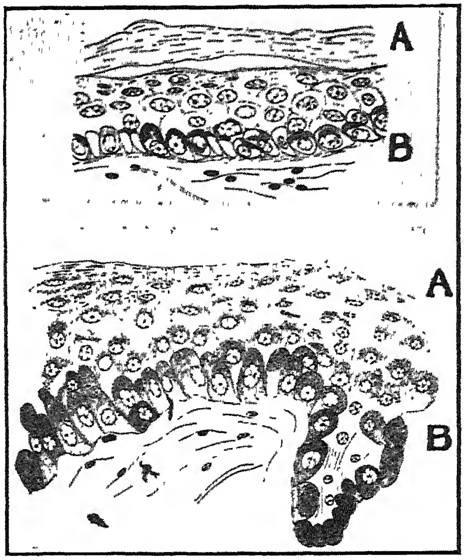


FIG 5. *Upper* · DRAWING OF A SECTION OF THE EPIDERMIS OF A BLONDE ("CROSS BETWEEN BLONDE AND BRUNETTE") IN LIGHTER BLONDES, FEWER BASAL CELLS CONTAIN STILL FEWER GRANULES; IN DARKER BRUNETTES THE BASAL CELLS CONTAIN MORE GRANULES (*a*) HORNY LAYER, (*b*) BASAL LAYER. *Lower* DRAWING OF AN UNSTAINED SECTION OF NEGRO SKIN, SHOWING THE DISTRIBUTION OF THE PIGMENT GRANULES IN THE EPIDERMIS. (*a*) HORNY LAYER; (*b*) BASAL LAYER. (JORDAN.)

Ultra-violet rays (shorter than 313 millimicrons) are specific in the cure and prevention of rickets (infantile and adult) and of infantile tetany.

Cases of extrapulmonary tuberculosis, including lupus vulgaris as a skin disease, are markedly benefited by careful exposure to sunlight or to the closest approximation to natural sunlight; *viz*, the energy emitted by a flaming carbon arc lamp. The benefits are due not solely to ultra-violet rays, either those specific in rickets or somewhat longer, but as well

to the light or luminous rays and to the heat or infra-red rays, which are so preponderatingly present in natural sunshine and carbon arc radiation. The reports of the results with the quartz mercury vapor lamp in the treatment of extrapulmonary tuberculosis are disappointing

Natural sunlight will hasten the healing of sluggish, indolent wounds This effect, however, is certainly not a specific effect of short ultra-violet rays. The effect is a deep one, indirectly through the circulation, and is brought about by wave-lengths that penetrate through the epidermis and part of the dermis. The surface action of ultra-violet wave lengths shorter than 315 millimicrons in large quantity is detrimental to the healing of wounds, unfavorably influencing the processes of repair. The influence is due to the longer ultra-violet, luminous and infra-red rays.

Ultra-violet rays alone do not lower blood pressure, but flaming carbon arc radiation does—that is to say, of a certain percentage (between 60 and 70) of persons with abnormally high blood pressure. Both systolic and diastolic pressure may be materially reduced (from 10 to 15 per cent.) by general carbon arc irradiation, given in erythema-producing doses, not too frequently repeated, so as to avoid adaptation. The "cure" is temporary, and the treatments have to be repeated, being given every ten days or two weeks in those whose pressure has been lowered by earlier more often repeated large doses (usually every fourth or fifth day).

Among diseases of the skin *lupus vulgaris* is the only one on which ultra-violet rays act specifically. In others it may have favorable action, but the improvement is not specific, and in others exposure to such rays may cause or provoke an attack.

Owing to the hypersensitivity of many infants and adults caution should be used in the use of sunlight, both natural and artificial. Over-indulgence, even in the normal, is foolhardy.

IN QUEST OF GORILLAS

VI. FAREWELL TO THE GREAT LAKES

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

At last we were ready to break camp and take leave of our kind friends at Tschibinda, especially M. and Mme Vierstraet and M. and Mme. Jooris, who were always so courteous and hospitable to us. Thus we were ready to start on our long journey from Lake Kivu southward to Albertville on Lake Tanganyika, thence westward by rail to the Lualaba River, thence alternately by boat and train north to the Congo, then down the Congo to its mouth, thence northwestward to West Africa. This journey took us from September 19, when we left Tschibinda, to November 14, when we arrived at Ozoum in the French Cameroon

It can readily be imagined that four men, with four native servants, living for six weeks at one spot, had unpacked and scattered around about every one of the thousand and one articles in our possession. There were therefore hectic times trying to fit the parts of a host of three-dimensional puzzle pictures into boxes, bags, etc., each of the right size for one porter's head. It may also be imagined how eagerly all the small boys in the neighborhood, including our blond-haired little friends, the sons of M. and Mme. Jooris, hung around and eagerly received numerous presents of red negative ribbons, empty negative spools and other junk. It need hardly be said of the old men, who stood around hopefully like vultures, that their appetite for discarded wooden boxes and tin cans was simply wolfish and that they grabbed and snatched things with frenzy.

McGregor and Engle, who walked down to Bukavu, taking with them part of our equipment, were the first to take leave of this delightful spot, where the thermometer seldom rose above 70 degrees Fahrenheit. We recalled that letters from home had spoken commiseratingly of the "awful heat in Africa," and that we had read them at night, sitting up snugly in our beds under three blankets and with woolen sweaters on! But now we were really going to face the music in the alleged steaming forest of Du Chaillu's gorillas

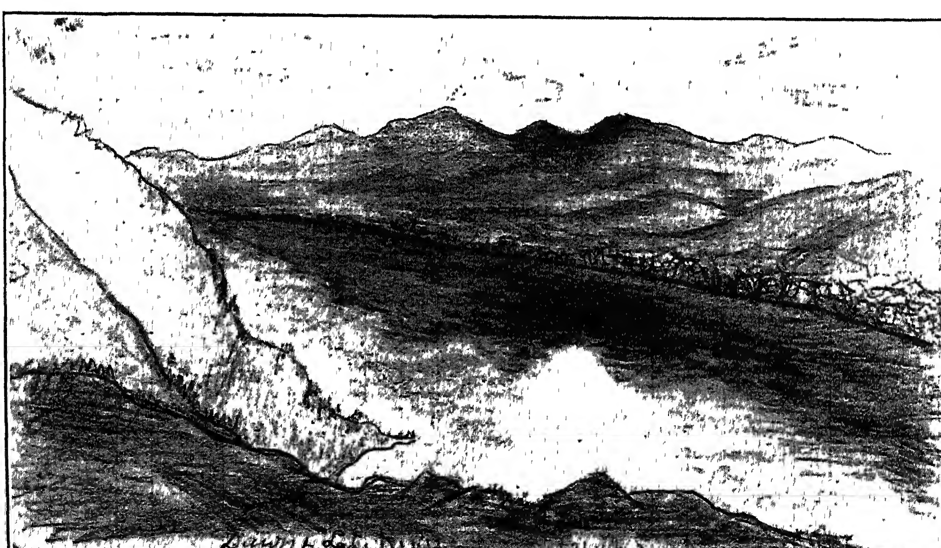
Well, farewell, Tschibinda! We'll carry with us innumerable memories of your glorious mountains and titanic clouds, and especially of the elusive and shaggy man-beasts of your leafy groves.

We left Tschibinda on a bright moonlight night and took a short path down the open mountainside to Mulungu, while the porters went around by the road. It was highly exhilarating to go quickly and lightly down this path, to see the dark-gray, wave-like mountains in the moonlight and to be guided to our goal, the village of Mulungu, by a single star-like light standing out against the mountains.

We arrived there late in the evening, expecting to find the ox-cart with the gorilla, together with the camion that was to take us to Bukavu. But we were told that the pole of the ox-cart had broken along the road and that porters had already been sent by our good friends in Mulungu to carry the gorilla the rest of the way down the mountain.

Photograph by H C Raven

"GROUP IN BRONZE"



Sketch from author's notebook

SUNRISE ON LAKE KIVU

The camion was there in front of its shed, ready to start early next morning. We accordingly spread our bed-rolls on a cleared field alongside the road and would have passed a very comfortable night had it not been for several interruptions. First, one of the thatched native huts near by caught fire and soon several of them were burning fiercely The people were taking it in very good part and were not a bit more vociferous than usual, their black bodies making an interesting scene as they moved about in the light of the fire. One of the houses was near the garage where gas and oil were kept, and we didn't quite like the idea of that, so Raven wakened the driver of the camion, who directed the natives to tear down the house next to the garage, that building being protected by its corrugated roof and wall.

The next diversion was caused an hour or so later by the arrival of the gang of porters bearing the body of the gorilla, which was duly deposited in the camion. In the flickering light of the campfire they looked like a choice collection of cannibals, but we knew they were innocent farm hands. Then there was a great outburst of jabbering while Raven lined up the gang and paid not only the porters but the several alleged headmen and policemen and assistants who, they assured us in thousands of words, had rounded the porters up to go after the gorilla. Then all settled down quietly for a couple of hours until 5 A. M., when we and our boys arose, rolled up our bed-rolls, put them on the camion and climbed aboard ourselves, getting under way before daylight, at 5:30.

Much as I disapprove of such early rising, I was well recompensed by the scenes that began to unroll themselves as we zigzagged down the rocky mountain road In a little while we came to a sharp down grade. On either side of the road opened out great pyramidal masses of contrasting deep shadows and intense lights, the latter from our camion headlights, the former from the immense mountains verging steeply downward in front of us. Near the bottom of the picture, where the shadows were blackest, a single spot of glowing red was caused by the embers of a small wood-fire.

After winding down grade for some time we came within sight of the lake. The golden-red sun was just piercing the heaped-up cumulus clouds and beginning to rise above the tops of the mountains on the other side. Here was a scene of glinting water, of mountain silhouettes in purplish gray shadows and of a lone twisted tree on a near-by promontory. We stopped a few moments and I got a hasty sketch of the scene, which I filled in later.

We arrived at Bukavu at 7:30 A. M. and found McGregor and Engle at the hotel there. I took a last glance northward at our old neighbor Mt. Kahusi, still standing guard over beautiful Tschibinda; then I found a niche in the pile of baggage on the camion and we started south on the return journey to Uvira at the head of Lake Tanganyika. Soon we were climbing the reddish mountains south of Bukavu and could look down on our left at the silvery trail of the Ruzizi River, winding between the hills where it exits from Lake Kivu. These bare hills were dotted with small groups of cattle, one of which that we peered at through our field glasses had the longest horns I saw in Africa

After a long time we came to the gray volcanic cones that have been the focus of titanic forces of uplift, which in times geologically very recent have broken up the whole region and exposed beautifully fresh sections of deep Archean rock.

The immensity and wildness at the peak of these stirring scenes were rather lessened by the presence of hundreds of noisy blacks at work on this great highway, which is constantly being improved

by the Bullamatari or "rock blasters" This name, by the way, was originally applied by the Congo natives to Henry M. Stanley, who once used dynamite to blast his way through some obstacle to navigation in a river, but the Belgians, who are his legal and spiritual heirs, worthily inherit also this name At this point the blacks swarmed like ants, but shamed the latter for wasting energy in running uselessly about. The blacks indeed are at all times masters of the shortest effective distance between the two points where a rock has to be picked up and cast down; when a man has to do this all day long, economy of effort is a sign of foresight and prudence, and no one who has watched the patient blacks carry heavy loads on their heads up steep mountain paths can deny that they are also capable of long and well-sustained action.

Gradually we descended from these precipitous heights to the open country that slopes gently down to the northern end of Lake Tanganyika. Here the erratic Ruzizi River seemed to wander around in a rather aimless way, not going through a deep valley of its own but rambling over very shallow and hastily improvised beds. Once we crossed a bridge over a newly cut bank and one could see that this region had received a lot of gravelly alluvial deposits in comparatively recent times, doubtless since the last great uplift to the north, which had increased the scouring power of the Ruzizi and perhaps caused it frequently to choke up its old beds and overflow into new courses The Encyclopedia Britannica (Art. Tanganyika) states that the Ruzizi River only reached the north end of Lake Tanganyika in 1906; but before that the river for a long period of relatively dry seasons may possibly have seeped into its own earlier gravelly deposits at the north end of the lake; anyhow we may be sure that the

Photograph by H C Raven

WAITING FOR CUSTOMERS. BUKAVU MARKET

Photograph by H. C. Raven
AFRICAN FLAPPERS

Photograph by H. C. Raven
A SOLDIER'S WIFE

present great elevation of Lake Kivu above Lake Tanganyika is a comparatively recent event, probably contemporaneous with the volcanic uplift to the south of it, and that the present Ruzizi valley is quite young.

At the ford of the Ruzizi, not far north of Luvunghi, we recalled an amusing incident that had happened at this spot. Several years ago Mr. Stephenson of Bukavu had just passed across this ford in an ox-cart drawn by many oxen. He had outspanned the oxen, which were grazing about quietly, while he was seated in the cart, dozing after luncheon. Suddenly a good-sized herd of elephants appeared on the other side and forded the stream just at this point. They swept past the ox-cart, paying no attention to its occupant, and as he had no gun with him he did not feel at all hurt by their neglect. The cattle never even lifted their heads and fortunately went right on browsing as if nothing had happened. He was beginning to breathe more freely when a young bull elephant, who had tarried a little behind the others, discovered him and showed signs of nervousness, lifting his trunk and apparently preparing to charge. The old ones, however, were moving ahead and on second thought the young one seemed almost to realize that he would only be making a fool of himself by upsetting a harmless ox-cart. At any rate, he hastened after the others and Mr. Stephenson got down and inspanned his oxen.

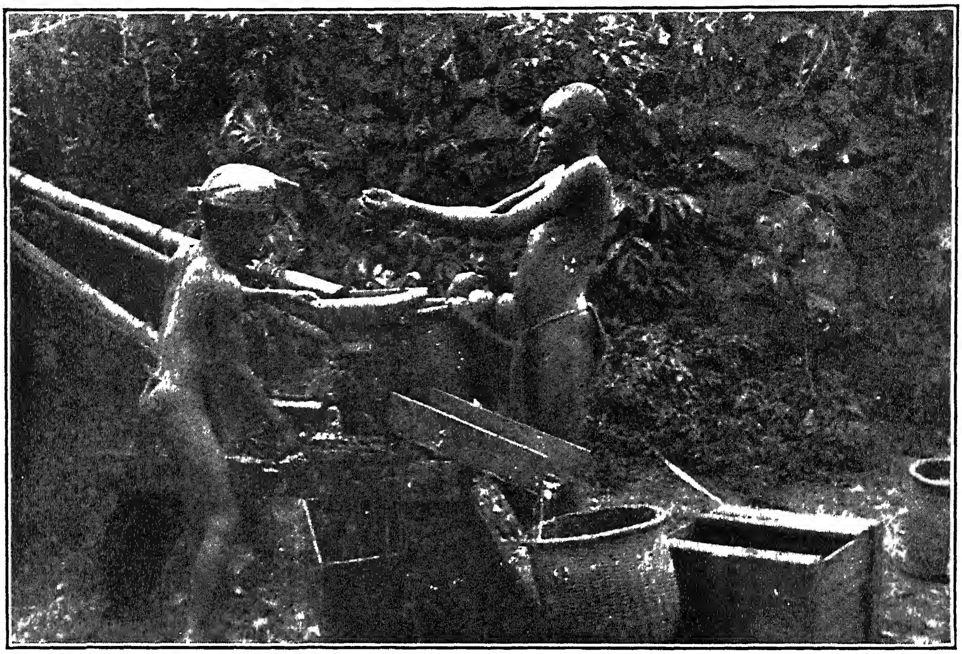
At Uvira we had as usual to wait several days for the next boat to Albertville on Lake Tanganyika, but we naturally shunned the "Greek Hotel" with its memories of mbusi (goat's meat) and applied for admission to the so-called English hotel. No cottages were vacant, but the manager kindly allowed us to set up our sleeping tents in the open yard of the hotel; there we were very comfortable, while good meals were served in the open-air dining-room, facing the great lake. A new hotel, of brick, was being built on these grounds in anticipation of

Photograph by H. C. Raven

GUARDING HER HUSBAND'S WARES

the new railroad running along Lake Tanganyika and Lake Kivu. The black bricklayers and mortar-mixers might have qualified as the world's low-speed champions, but the new hotel, like the railroad itself, was growing as the great nests of the termites grow, through the summation of almost infinitesimally small increments of individual effort.

During this time of waiting Dr. Engle and I went several times to the Swedish Lutheran Mission a few kilometers north of Uvira, where through the kindness of the Reverend Mr. Windberg and his colleague, Mr. Carlsson, we secured footprints and height measurements of eighty people, including men, women and children. One of these natives was a youth with the longest arms and shortest legs I have ever seen on a human being, since his width across his outstretched palms considerably exceeded his standing height. Some of the people had splendid wide flat noses of what I called the three-bulb type, that is, with one median and two lateral bulbs in nearly the same plane. The missionaries and their families were cultured and pleasant people, who lived in a large white house overlooking the lake From their broad verandah with its stately wooden columns we had a fine view of the northern end of the lake. There in the old days many hippopotami disported; but now, our hosts told us, only a solitary old bull still hides in the reeds. On several occasions the missionaries very hospitably entertained us, and it was a genuine pleasure to sit down to a table with spotless linen, fine china and excellent food One of their guests, a Swedish gentleman who had been an officer in the Belgian colonial army, spoke of the Belgians' humane policy of forbidding the use of the lash on the natives. He added that this sometimes had its practical disadvantages, as in the case of an unruly black boy who had deliberately smashed



Photograph by H. C. Raven

NATIVES PREPARING COFFEE AT A KIVU MISSION

a second large and beautiful china dish just because he had been fined for breaking a first one.

On the way home from the mission one day we saw in the distance several women and children surrounding a cylindrical wooden vessel. Each one had a long post in her hands and took her turn in lifting it up and smashing it down on the grain in the vessel. Merrily the posts shot up and down like pistons on a crank-shaft and, one is tempted to say, almost as fast.

While at Uvira I again indulged my habit of wandering about the open hills and along the shore of the lake. The yellowish-gray crystalline mountains that crowded the lake shore were peculiarly satisfying, partly because they gave me a glimpse of rocks of incredible antiquity but which had only recently been pushed up from the depths so that the forces of erosion could expose them. Viewed in front they were like superimposed alternative rows of inverted V's with widely spread slopes and with apices rounded off. Seen in profile against the sky just before dusk they ran down to the lake shore in bold jagged masses of dark purple Their contours were evidently produced by the present erosion or drainage system, dating back perhaps only a few hundred thousand years, but their rocks had been crystallized at great depths possibly a thousand million years ago, long eons before the dawn of living matter.

On September 25 we broke camp at Uvira and sent our luggage to the steamer wharf near by at the small village called Kalundu. Here a creek comes out through a fine gorge between steep and imposing masses of crystalline rock. As the steamer we were to take was still far out on the lake, I could not resist the temptation to wander a little way up this gorge to admire the drab mountain masses, often blackened by bush fires or

splashed with yellowish brown and olive patches. Here and there brilliant red flowers on flamboyant trees stood out from the somber background. Looking over the lake I could see the *Baron d'Hanis* in the distance and behind her a rain cloud rolling toward us. Soon there was a fine display of lightning and a few big drops, which eventually became a downpour. For a while I stood on the recumbent trunk of a large tree with extremely broad leaves and watched both the rain and the ants narrowly. The big leaves served as an umbrella until the downpour came. Then I broke cover and dashed down the hill, arriving just before the *Baron d'Hanis* touched the wharf, fairly wet but with some glowing memories of my last ramble among these strange exotic scenes.

At the wharf we each gave a farewell present to Behongo, our sleek-looking boy with the beautiful teeth, whose smiles cheered our departure. The other three boys elected to go with us into the unknown world, but Behongo sensibly enough chose to stay with his wife in his home town.

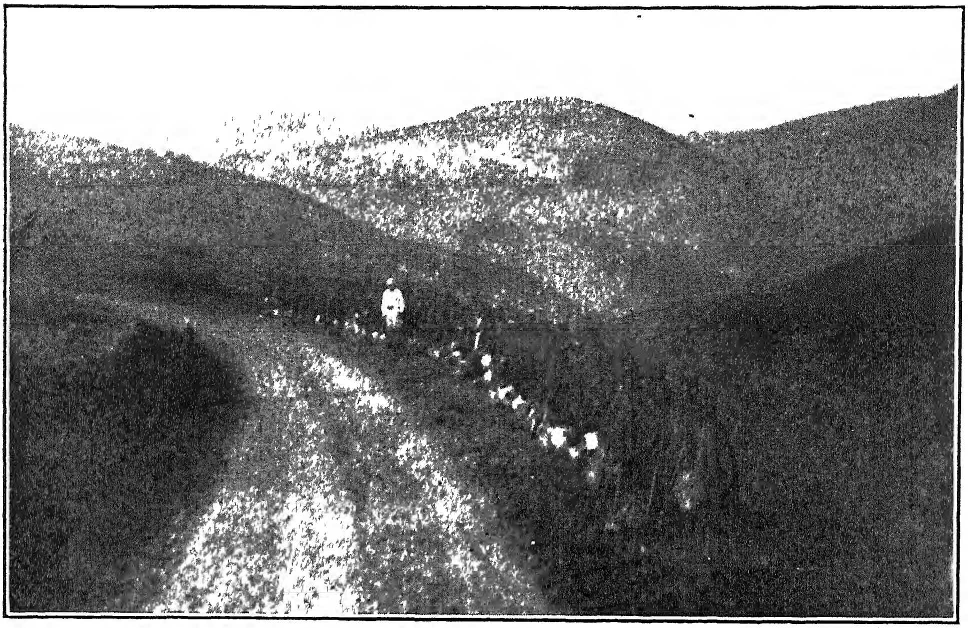
As we sailed southward near the west shore of the lake we saw that the type of bluntly serrate crystalline mountains with which we had been familiar at Uvira extended parallel to our course and for a long distance southward along the western shore, but as we receded from the great disturbance which had produced the jagged mountains south of Lake Kivu, the height and boldness of the peaks sensibly decreased.

At one place we passed a tiny rocky island near the shore, which had been named "New York Herald Island" by Henry M. Stanley, in memory of James Gordon Bennett's part in sending him to rescue Livingstone. During the greater part of our journey in Africa we had been and would be going over part of Stanley's routes, from the east coast across the rift valley to Lake Tanganyika, thence westward to the Congo, down the Congo to Stanley Pool, and so on to the coast. But while we went in trains, automobiles and great river steamboats, he had traveled on foot, often in spite of hostile tribes who tried to block his advance. Such is the contrast between the Africa of to-day and the classical Africa of the great explorers.

After some hours of steaming we touched at Baraca; this lies in a deep bay, flanked by a high ridge called Burton Promontory, which juts out obliquely into the lake for many miles This promontory reminds one of the long mountainous island of Kwidjwi in Lake Kivu. It would seem that the horizontal tension which caused the great rift in the rocky plateau had been resisted perhaps by the rock of the Burton Promontory, so that the rifting force had divided into two very unequal parts, the greater part producing the main valley that is now filled by Lake Tanganyika, the lesser fork becoming the bay of Baraca. The hills of this promontory have been worn down so that they have lost their serrate tips and present only a slightly irregular skyline; in other words, this seems to be a relatively ancient or mature drainage system and the land may have escaped any marked uplift in relatively recent times, which would have rejuvenated erosion and produced deep valleys and serrate peaks.

In a canoe near the wharf at Baraca was a little boy, one of those who were diving for coins thrown out by the passengers, who proved to be one of those individuals whose face one never forgets. It reminded me of the large-eyed portrait masks that the Egyptians used to put on their royal coffins. Never have I seen such an imposing large face or such enormous eyes It is true that we had seen many large-eyed Negroes around the south end of Lake Kivu and the north end of Lake Tanganyika, but in this beautiful boy the character seemed to reach its climax.

Another thing of special interest at



Photograph by H C. Raven

BELGIAN HIGHWAY OVER THE MOUNTAINS SOUTH OF LAKE KIVU

this point was the presence in the water of many small jellyfishes, which, being closely related to marine types, are regarded by some zoologists as souvenirs of a very distant time when the great Rift system had an opening to the sea at its southern end below the Zambesi River.

We then steamed northeast, rounded the tip of Burton Promontory and headed southeast for Kigoma

To summarize at this point my observations on the contours of the mountains, it may be said that as we passed southward the mountains gradually became worn down into low hills and one could see many intermediate stages in this process of degradation, from stretches south of Uvira, where the drainage slopes of the mountains resembled a system of inverted V's superposed one above the other, to the other extreme of Kigoma, where the limbs of the V were opened out very widely and the top rounded off so that only a low convexity remained.

As we had to wait for a night and a day at Kigoma, all four of us walked out to the "elephant's foot" rocks and netted a few of the bats there as they flew out of their cave. McGregor got some interesting cinema records of these animals, which had enormous ears like those of a jack-rabbit and pointed muzzles A huge baby clung to the nipples of one bat. On the way along the lake shore Engle picked up a large thin cycloid fish scale, which reminded me somewhat of a tarpon scale. The identity of this fish puzzled me a good deal and I shall presently relate how the puzzle was solved.

Late that afternoon I climbed one of the rounded high hills back of Kigoma, following a winding path which led past plowed or empty fields to the crest. A small leaping mammal[1] easily escaped me. A few perfectly gigantic ants were safe from any interference from me.

[1] It was probably one of the "jumping shrews."

The dried dung of a large carnivore, possibly a hyena, added another African touch to the day. Looking west from near the top of the crest, I had a fine view of the rocky promontories, including the "elephant's foot," that guarded the bay of Kigoma, and a little later I faced the crimson sunset.

At the very crest of the long hill was an abandoned native village, which just before dusk was haunted with an uncanny stillness Why had the people abandoned such good houses? If sleeping sickness had grievously afflicted the people, would not the government have burned the houses? Had the chief died and had the witch-doctors then declared the village itself taboo? But there was no time for further reflections. I gave one glance down the long hill on the other side of the crest to a vast open rolling country dotted with trees but with no visible signs of human habitation, then turned and hurriedly descended the long hill to our ship.

During the night the *Baron d'Hanis* crossed the lake and landed us the next morning at Albertville. As we steamed toward the bay we could see a system of diminutive mountains behind the town, perfect pygmies in fact, but nevertheless in a fully adult, not to say senile stage of development. For their little inverted V's still retained clear evidence of having arisen through the erosion of mountain streams, but only the tops of the V's were worn down into the well-rounded convexities of old mountains At one point I could see with my field glasses some oblique ledges of dark purplish-red stone, which possibly belonged to the Lualaba system (Lower Permian).

Albertville is a very bustling and intensely modern little city with a long street of white hotels and shops along the bay and many smart-looking residences along the hilltops. When Mr. Raven was there ten years ago, about the only white man present was the Belgian administrator, who lived in a small house built by the natives The town is the terminus of the railroad, which runs westward to Kabalo on the Lualaba River and is thus the outlet of the commerce of the Upper Congo.

Late that afternoon Raven and I walked northward a mile or two to the Lukuga River, which is the outlet of Lake Tanganyika and which he had studied ten years ago. This river is of interest because it seems to be relatively recent in origin. It is one of the small tributaries of the Lualaba or Upper Congo River and thus its waters flow west toward the Atlantic. There seem to be at least two possibilities as to the way this river arose. After the high plateau had split asunder, making the excessively deep cleft which is now filled by Lake Tanganyika, the waters naturally flowed into it. Sooner or later the southern exit was pinched off by further earth movements and the deep cleft filled up until it began to spill over at a certain point and thus gave rise directly to the Lukuga River. The small gorge through which this river passes would thus have been worn down by this river alone A second and perhaps less probable hypothesis is that the gorge of the Lukuga has been worn down through the cooperation of two streams, one flowing east into the lake, the other flowing west to the Lualaba River. Under certain circumstances the headwaters of one side might capture those of the other, and both systems might then cooperate in cutting down the watershed between them, which is now represented by the present gorge.

When Mr Raven was at this place ten years ago, he and his colleague, Dr. Shonts, made a series of rough measurements of the run-off of this river by timing the average rate of the current and multiplying it by the area of the cross-section, which they obtained by soundings at various points. The amount of

Sketch from author's notebook

DRAINAGE SLOPES ON WEST SHORE OF LAKE TANGANYIKA, SOUTH OF UVIRA, WITH NEW YORK HERALD ISLAND IN THE FOREGROUND.

water drained from Lake Tanganyika by this river is not great, but as time goes on it will probably slowly increase. However, the lake is in no immediate danger of being badly drained by this little nibble on its high wall, as it is 4,708 feet deep and it would take tens of thousands of years for the Lukuga to wear down its gorge to any appreciable extent.

Along the broad lake shore, near the Lukuga outlet, there was a wide sloping beach of fine sand, upon which were countless multitudes of old snail shells and pools of fresh water filled with tens of thousands of pollywogs—a typical example of both the almost incredible fertility of nature and the dominance of particular types in suitable places

Before turning our faces forward to the new scenes that greeted us on entering the Congo basin, let us review briefly some of our outstanding impressions of East Africa and the great lake region. First, at Mombasa and Dar-es-Salaam on the east coast we had seen settlements where the Hamitic and Arabic influences on the Bantu Negroes had been very potent. Geologically this was on the strip of the coastal plain, with shell and coral rock that had been subjected to moderate elevations and depressions. Then on the railroad we had gone westward a little way to the escarpment on the edge of the enormous rocky plateau of inconceivable antiquity which forms the crystalline mass of central Africa and which has never been flooded by the ocean. Next we climbed the escarpment and began the long slope downward into the trough of the "great rift" system, which extends north and south from below the Zambesi up through the Red Sea to Palestine. Traversing the wide shallow depression of central Tanganyika, which is relieved by granite hills of majestic wildness and desolation, we had spiraled up the divide and then descended somewhat to the western or Albertine rift occupied by Lake Tanganyika and its northern relatives, Lake Kivu and Lake Albert. These owe their existence to great subterranean disturbances which forced certain great blocks upward, opened great rifts and allowed long strips to settle, while Lake Victoria was formed in a basin-like de-

pression perhaps corresponding to the basin of the Congo River (Bailey Willis)

Traveling north on Lake Tanganyika and then up the Ruzizi River to Lake Kivu, one of the highest lakes in the world, we had finally gone up into the mountains west of Lake Kivu, where at altitudes of 6,700 to 9,000 feet we had been on the "ridgepole" of the continent in this region. Now we had come away south, many hundreds of miles, and were about to go down the western side of the ridgepole into the Congo Basin. In connection with field notes and sketches of the Ruzizi River, which carries the overflow of Lake Kivu down 2,600 feet to Lake Tanganyika, I had become interested in the problem as to what had happened when the terrific displacements south of Lake Kivu had thrown a great barrier across the old Rift Valley.

In general, while we were in the region of the southern end of Lake Kivu and the northern end of Lake Tanganyika we had been among peoples which were apparently a mixture of the "cattle-keeping aristocracy" from the northeast, the forest Negroes, the pygmies, allied with those of the Congo Basin, and the Bantu Negroes of east Africa. Thus we had seen a part of the "melting-pot" of Africa, and it was therefore not surprising that these natives displayed an immense range of variability, both in anthropological measurements and in their personal individuality, examples of which have been given above.

In the mountains west of Lake Kivu we had been in the home of the eastern or Mountain Gorilla, an outpost of gorilla territory on the extreme eastern margin of the great forest, these gorillas being now widely separated from their western relatives, the gorillas of the Cameroons and the Gaboon of French Equatorial Africa.

We had found these gorillas to be extremely shy, retiring animals, wanting nothing so much as to be let alone and repelling the snooping advances of white busybodies. We had found them going in small roving bands of variable number, making their beds for the night under and in trees with spreading branches, and consuming a prodigious quantity of succulent vegetation. The big males had been quick to charge at the persistent hunter, and on the third charge a certain old male had been dropped only a few feet away from Raven's gun. Raven had secured two fine specimens, he had injected them with preservatives, they had been shipped to our anatomical laboratories in New York for further study and we had accumulated a good many observations on their habits.

All that we had seen so far was in harmony with a vast amount of other evidence that the gorilla has been a relatively late offshoot from the broad group of *Dryopitheci* or ancestral man-apes that gave rise also to the chimpanzee and to man; more specifically, that the gorilla represents a branch which has become specialized, by means of its cross-crested molar teeth and greatly enlarged abdomen, to eat enormous quantities of succulent vegetation, without, however, losing the essentially prehuman character of its digestive tract.

As the western shore of Lake Tanganyika is also the eastern limit of the Congo forest, at Albertville we were on the high outer margin of the Congo Basin. Hence it was not surprising to find the fishes of Lake Tanganyika closely related to those of the Congo system.

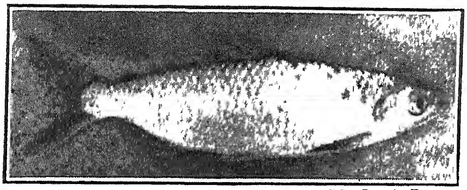
On the lake shore at Albertville, just about dusk one afternoon I came to a place where two gangs of men were starting to haul in a large seine. Eagerly I awaited the sight of the catch, which consisted mostly of fine large cichlids, like those I had seen in Lake Kivu. But one

THE MOUNTAIN GORILLA AT HOME

FROM A PAINTING BY ARTHUR JANSSON, UNDER DIRECTION OF H C. RAVEN.

beautiful silver fish about ten inches long excited my cupidity and I promptly grabbed it. A Portuguese kindly told me in French that it was not much good, but I told him I was a student of fishes and that satisfied him. The owner asked four francs (twelve cents) for it, probably an exorbitant price, but I paid it without haggling and carried it off in triumph to the hotel, for it was one of the classical family of African characins, the first I had seen in Africa, although I had studied their skeletons at the museum. It was resplendent in large silver cycloid scales, which left no doubt of the identity of the single cycloid scale which we had picked up at Uvira. I made a rough sketch of it, which afterward showed that this fish was at least related to the genus *Alestes*. It had large eyes and small mouth studded with sharp little teeth arranged in vertical bands; its body was fusiform; the anal fin was elongate and it had the very wide tail and caudal peduncle of a powerful swimmer and quick snatcher of living prey As all our preservatives were packed up and inaccessible, I had to give this silvery beauty away the next morning.

To the student of the evolution of



Photograph by Herbert Lang
AFRICAN RELATIVE OF THE "MAN-EATING FISH" OF SOUTH AMERICA.

fishes the African characins are of great interest Their nearest allies are the famous piranhas, or man-eating fishes, of South America. The headquarters of the highly diversified family of characins is in South America and the presence of a few characins in Africa has been cited by those geologists and zoologists who believe that in former geologic ages there was a land bridge stretching across the Atlantic from South America to equatorial Africa There is indeed a great deal of evidence for the reality of such a bridge in the present and past distribution of many forms of marine invertebrates, as recently reviewed by Professor Schuchert. It is also a curious fact that among the marine mammals the Florida manatee (*Trichechus manatus*) has a very close relative, *Trichechus senegalensis,* off the coast of Africa (Hatt, R. T., 1934); although manatees may be swept out to sea by storms, they are strictly herbivorous animals feeding on vegetation of rivers and estuaries, and there is no evidence that they could live through a transatlantic trip without food. The fossil snakes, chelonians and other extinct vertebrates of the Fayûm in Egypt, described by C. W. Andrews, were also cited by him in support of the well-known conclusion of the conchologist Von Ihering that a long archipelago at least stretched from the Amazon region to the Guinea coast On the other hand, the paleontologist, W. D. Matthew, in his work on "Climate and Evolution" showed that the tapirs and many other mammals of South America had reached there by immigration from North America. In extending the principle of the northern origin of forms now found in the southern continents to all classes of vertebrates Matthew may have gone too far

Photograph by Herbert Lang
HEAD OF *Hydrocyon,* LARGEST AND FIERCEST OF THE AFRICAN CHARACINS.

In any case, a recent comparative study of the skeletons of African and South American characins by the writer and his assistant, Mr. G Miles Conrad, brings out clearly the very close relationship of these two lots of fishes, which are now separated by a wide ocean.

This characin of Lake Tanganyika was evidently allied with those of the Congo River, and its presence emphasized the fact that on the west shore of the lake, or at least in the hills back of it, one would be standing on the outer rim of the immense drainage basin of the Congo River, which we were to enter the next day.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)

PLAYGROUND OF A SCIENTIST

By EVA V. ARMSTRONG

CURATOR OF THE EDGAR F. SMITH COLLECTION IN THE HISTORY OF CHEMISTRY, UNIVERSITY OF PENNSYLVANIA

Most of us come into this world with a pack on our back, invisible to the eyes of childhood, carried lightly through adolescence, but as the days pass the pack mysteriously increases in weight. No longer can we nonchalantly ignore it, so we decide to open it—to lighten it or to divest ourselves of it, if possible. Besides we are a bit curious by this time. We break the seal, and out steps a lively genie. We recognize him at once—just the same old genie we read about in Hans Andersen—by all the traditions he ought to let us make a magic wish. A gallant yacht? King Midas touch? A lovely lady? But the genie says nothing of wishing, and we stare a little as he hands us a violin or a scalpel, a pencil or a pick and shovel, architect's tools or a test-tube. And from that day our doom is sealed. We enter the world of work. Tempered with a little laughter and a little love, we find our days full, pleasantly so at times, unbearably so upon other occasions. We are jostled, praised, blamed, sought after, neglected, exploited, loved and hated We continue to work. On a weary day, battered on the main highway and spent with the struggle, we enter a quiet street and open a door into a garden. Here are shrines laden with strange objects—butterflies, postage stamps, objects of wood, bronze and glass, strange hieroglyphics, pictures, manuscripts and old tomes. Before the shrines we see the devotees, seemingly rapt in the beatitude of angels. As we timidly approach an altar a curious old volume falls at our feet. Intrigued by a strange device on the cover, we pick it up. Its pages are stained, its print curious, its illustrations have a strange symbolism, its wormed pages make us realize that we have neglected to think about bookworms —does one ever actually see a bookworm, or only his work? Is he wholly anonymous? We turn the pages of our volume and ponder its age. A strange, unworldly peace descends upon us, there is a curious twitching in our fingers, we surreptitiously slip the book into our pocket and for better or for worse, in sickness or in health, we have become a book collector True, we must leave the enchanted garden, we must eat, love and work—but we carefully mark the spot that we may return anon. We have found a way of escape, where at times we may in enchantment

> . . . he buried,
> The world forgetting, by the world forgot.

It is said that the personality of the collector creates the life of the collection. Is it cold, colorful, vital, inspiring, stupid or inane? So perchance is the collector. It is well to know him before engaging to view his treasures.

Dr. Edgar Fahs Smith, whose collection of rare books, prints and manuscripts pertaining to the history of chemistry is the subject of this sketch, was born in York, Pennsylvania, in 1854. Educationally he was a product of the old-fashioned curriculum, consisting of Latin, Greek and the humanities. At the age of sixteen he taught Latin. This training stood him in good stead, when later at the University of Göttingen, in Germany, he was required to write his doctoral thesis in Latin, to defend its grammatical construction and chemical content in German before the assembled faculty, himself arrayed in evening dress, white gloves and high silk hat.

Edgar F. Smith
5/28/1926

Possessed of an inherent love of books, as a boy he supplemented the single volume which he received each year at Christmas by his own purchases, made as a result of strenuous toil in loading coal wagons, working on a farm during vacation periods and finally as a printer's devil. Here he learned to set type and to print with an old-fashioned hand press. The art of printing attracted him, and he acquired in time an appreciation of fine typography At the age of seventeen, he became publisher and editor of an amateur paper entitled *Our Effort*—"printed every month at the low rate of 50 cents a year, in advance" He wrote the articles under various noms-deplume, set the type, printed the journal, which he then proceeded to sell in a house-to-house canvass. Its early demise occurred upon a day when the publisher was unable to pay for the paper required for a forthcoming edition.

As a boy, Dr Smith longed for the books of Oliver Optic and of Captain Mayne Reid, desires infrequently attainable by him. It is interesting to note that later in his career, in a secret recess of an old-fashioned desk from which he administered the affairs of a great university, there reposed—unknown to the serious and august members of the faculty who visited him—a collection of Mayne Reid and Oliver Optic books. Dr. Smith always referred to them as "my boy books" and was guilty on rare Saturday afternoons of leafing them over. It was a secret joy which he had

Educator, chemist, author and provost of the University of Pennsylvania, Dr. Smith found little time for holiday or recreation. He believed in the doctrine that "it is better to wear out than to rust out," and said that rest came to him through change of work. He referred to the collection of rare books and prints which he assembled as a "playground of the mind." He entered this playground with the pure and unalloyed pleasure of a child in a toyshop. Administrative worries, abstruse scientific problems, personal cares forgotten, he wandered about, happy and enthralled, with the immortals of his science. A sympathetic and understanding friend of man, he entered the minds and hearts of the philosophers of long ago. They spoke to him through yellowed pages. He grew in intimate knowledge of them and their work

With the alchemists, Dr. Smith sought the philosopher's stone, the transmutation of metals, the elixir of life. In weird cellars and old laboratories he shared their failures and successes, their comedies and tragedies. In a Benedictine monastery he discusses with Basil Valentine "The Triumphial Chariot of Antimony," and gently chides him for his penchant for antimony as a nostrum, reflecting upon the legend that it derives its name from the fatal effect it had when used as a medicine upon the unfortunate friars (anti-monk); with the honest old alchemist, John Dee, he meets Queen Elizabeth and journeys with Dee and his rogue friend, Edward Kelley, to the Court of King Rudolph II of Bohemia, where gold is sought by transmutation in a little street which may be seen today by visitors to Prague. Dee returns to England, but the death of the villain in the piece, Edward Kelley, in a fall while trying to escape from a tower where he has been imprisoned by the King for his deceptions, seems an act of good old-fashioned justice. True, there are those who scoff at alchemy, but the preface in an old book assures Dr Smith that "alchemy is indeed the mother of chemistry, and it is not the daughter's fault if the mother is absurd." Interested and amused by the bombastic Paracelsus, who says that the true purpose of chemistry is to make medicine and not gold, Dr. Smith reflects upon the vanity of man. The chemical oven of Leonardo da Vinci intrigues him, as do the experiments of Roger Bacon on the making of gunpowder. He listens to the

ROBERT BOYLE, 1627–1691

ENGLISH CHEMIST AND EXPERIMENTAL PHILOSOPHER. A FOUNDER OF THE ROYAL SOCIETY. "MR. BOYLE, THE ORNAMENT OF HIS AGE AND COUNTRY. . . . WHICH OF MR BOYLE'S WRITINGS SHALL I RECOMMEND? ALL OF THEM. TO HIM WE OWE THE SECRET OF THE FIRE, AIR, WATER, ANIMALS, VEGETABLES, FOSSILS: SO THAT FROM HIS WORKS MAY BE DEDUCED THE WHOLE SYSTEM OF NATURAL KNOWLEDGE"—BOERHAAVE. REPRODUCED FROM AN ENGRAVING BY GEORGE VERTUE, 1739, IN THE EDGAR FAHS SMITH MEMORIAL COLLECTION, UNIVERSITY OF PENNSYLVANIA.

conversation of Robert Boyle with Dr. Harvey on the circulation of the blood. He enters the bowels of the earth with Agricola to study mining and metallurgy with that sturdy soul, who, despite his great achievements and his gratuitous care of the sick in the village in which he lived, upon dying was refused a resting place there because of his religious views. And Dr Smith muses upon the thought that three hundred and fifty years later, Agricola's *De re Metallica* (1556), the most important contribution to metallurgy for a century of time, should find new life in English dress at the hands of a twentieth century mining engineer and President of the United States of America, with the scholarly assistance of the first lady of the land. With Joseph Priestley, the discoverer of oxygen, he lives through the riots at Birmingham, England; Priestley's emigration to America, his friendship with Franklin, Washington, Jefferson, and his fundamental contributions to science in America. He mourns for the ill-fated Lavoisier, who overthrew the doctrine of phlogiston, so staunchly supported by Priestley, and who brilliantly established the foundations of modern chemistry, only to be denounced by the mob of the French revolution, and lost to his young wife on the guillotine on the same day that her father was executed. Galvani's experiments in electricity recall to him Dr Harvey Cushing's note in Osler's Catalogue: "Who, says Helmholtz, when Galvani touched the muscles of a frog with different metals, and noticed their contraction could have dreamt that all Europe would be traversed with wires, flashing intelligence from Madrid to St. Petersburg with the speed of lightning? . . ."

Is it strange that Dr. Smith returned from these marvels to the everyday world with eyes alight, inspiration in his heart and a consuming, burning ambition to introduce his old friends to his new friends. This he did in informal talks which held his audiences under a spell from which they awakened only with the closing word, and in a series of delightful essays and books in which he put flesh upon the skeletons of the pioneers of the science, making them living, breathing personalities Surely, at journey's end these friends of the long-ago awaited eagerly to greet him as one known to them and dearly loved for his remembrance of their deeds. Eternity can not be long enough for all that must be said.

One of Dr. Smith's peculiarities as a collector was his refusal to have a card catalogue of his treasures; he would as soon have thought of making a card catalogue of his friends. No unsightly library number must deface them—he knew his books and pictures. If he placed one of them on a shelf he could go to it weeks, even months later, and put his hand upon it. One of his characteristics was a remarkable and somewhat uncanny memory for books and for people. Alumni of the University of Pennsylvania, returning after an absence of many years, had only to appear in the ever-open doorway to be called by their first names. A favorite sport at alumni reunions of ten or twenty years was to line up and be recognized by "the Doctor." He seldom failed. His sincere and friendly interest in young men led President Thwing, of Western Reserve University, to call him "the best-beloved college president of his generation."

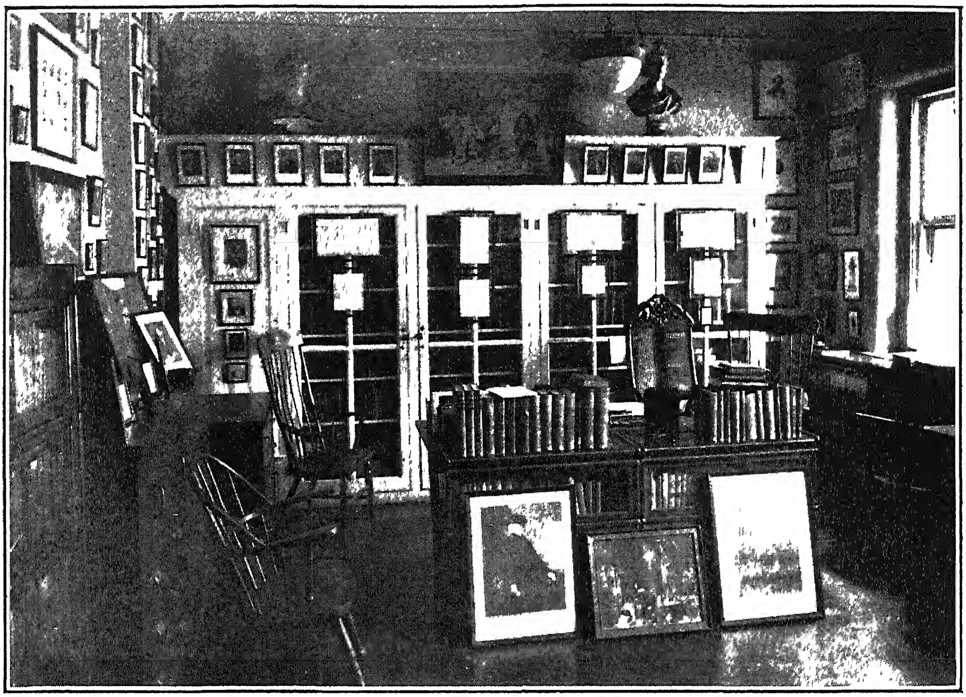
The cost of books in the field of old chemistry was comparatively low when Dr. Smith began to collect them. It has increased materially since other scientists have fallen from grace, but not to the point where a poor but honest college professor may not pick up a few examples in early science without placing his family upon the dole. Pencil in hand, Dr. Smith carefully scanned the magic catalogues. Representing the university abroad at stately functions, he yet found time to haunt old book shops—Berlin, Munich, London, Paris, Milan and Rome—all knew his happy, eager quest.

The story of the beginning of his collection is best told in his own words, written in 1921:

> My interest in the history of chemistry began more than 30 years ago. . . . As a student, the time honored volumes on the history of chemistry had been dutifully read by me, but with shame I confess that over many of these volumes I fell fast asleep. Yet when the life story of the makers of our science came to me, then quite a different attitude towards its history was awakened in me. . . I took to visiting out of the way second hand book-shops—usually on Saturday afternoons, picking up here and there a stray volume devoted to chemistry. The first pamphlet I purchased, costing ten cents, contained something about the compound blowpipe. There was a well defined picture of a piece of apparatus in it. Some obsolete cumbersome form of apparatus that someone—at some time—had printed. To him doubtless it was

A PAGE FROM BOYLE'S BOOK

Engraved title-page of a Latin edition (1669) of the first scientific work by Robert Boyle, entitled "The Spring and Weight of the Air" "The generalization which carried Boyle's name to posterity, i.e., that the volume occupied by a gas is the reciprocal of its pressure, did not appear in the first edition (1660), but was brought forth later (1662). . . "—J. F Fulton, "A Bibliography of Robert Boyle" Original in the Edgar Fahs Smith Memorial Collection, University of Pennsylvania.



A VIEW OF THE OFFICE OF FORMER PROVOST EDGAR FAHS SMITH (1854–1928) OF THE UNIVERSITY OF PENNSYLVANIA. THE COLLECTION IN THE HISTORY OF CHEMISTRY ASSEMBLED BY HIM IS NOW LOCATED THERE.

precious. To me it had little or no meaning, so I laid it carefully away. . . . In due course came an awakening, somewhat after this manner. I'd been discoursing on the oxy-hydrogen flame. I was well pleased with my presentation of it, when a lad not noted for an inquiring mind, asked who invented the oxy-hydrogen flame—how long has it been known—how did its discoverer happen upon it—was it of French origin or German? Quite a few questions from one untutored mind, you'll grant, and I acknowledge I could not answer any of them. What I said to the student I do not recall—but probably one of those camouflage answers even professors have been known to give—just to recover their breath, so to speak, that is to get time to look up the subject under discussion. You may rest assured I did look up the oxy-hydrogen flame, but nowhere did I discover anything about its origin. You may imagine that I was far from being happy—yes, very far. I ventured to consult several colleagues in a very cautious way. They gave me no aid. The questions couldn't be forgotten, when some good angel whispered to me—look over your old chemical books and pamphlets—that stuff you've been gathering and filing away with such solicitous care. At once I brought forth my old documents, and right there among them was my old purchase at ten cents. And there was the original account of the old compound blow-pipe by Robert Hare. Oh! it was a treasure, and I was able to tell my students a story about the oxy-hydrogen flame such as no text-book in their accessible library could give them.[1]

Fine bindings, first editions, the rare and the unusual appeal to many. These are represented in Dr. Smith's collection, but he assembled the material primarily for content of publication and for personalities. There are classics in chemistry as there are in literature. These were of great interest to him. He referred to chemistry as the "human science"—"It comes close to everyone's hearth and home. In every employment we feel its influence or want its aid."

[1] "Observations on Teaching the History of Chemistry," by Edgar F. Smith. *Jour. Chem. Education,* 1925.

JOH. JOACHIMI BECCHERI, D.
SPIRENSIS GERMANI
Sacr. Cæſ. Majeſt. Conſil. & Med. Elect. Bav.

PHYSICA
SUBTERRANEA
PROFUNDAM SUBTERRANEORUM GENESIN,
E PRINCIPIIS HUCUSQUE IGNOTIS,
OSTENDENS.
OPUS SINE PARI,
PRIMUM HACTENUS ET PRINCEPS,
EDITIO NOVISSIMA
PRÆFATIONE UTILI PRÆMISSA, INDICE LOCUPLETISSIMO ADORNATO, SENSUUMQUE ET RERUM DISTINCTIONIBUS,
LIBRO TERSIUS ET CURATIUS EDENDO,
OPERAM NAVAVIT
ET
SPECIMEN BECCHERIANUM,
FUNDAMENTORUM DOCUMENTORUM,
EXPERIMENTORUM,
SUBJUNXIT
GEORG. ERNESTUS STAHL, D.
PROF. PUBL. ORDIN. HALL.

LIPSIÆ,
EX OFFICINA WEIDMANNIANA,
ANNO MDCCXXXIIX

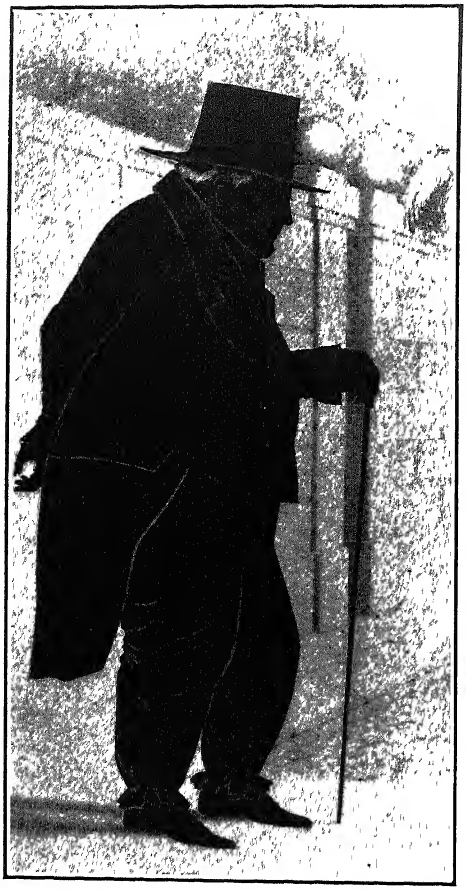
PAGES FROM BECHER'S BOOK.

SYMBOLIC PLATE AND ENGRAVED TITLE-PAGE OF "PHYSICA SUBTERRANEA," THE MOST IMPORTANT WORK OF JOHANN JOACHIM BECHER, 1635–1682. HIS THEORY OF THE CONSTITUTION OF MATTER FORMED THE BASIS OF THE PHLOGISTON THEORY AS INTERPRETED AND EXTENDED BY STAHL AND HIS FOLLOWERS. ORIGINAL IN EDGAR FAHS SMITH MEMORIAL COLLECTION, UNIVERSITY OF PENNSYLVANIA.

The history of chemistry he regarded as the cultural side of the science. In learning to know his books, he said: "My early drill in the languages aided greatly; indeed, the dead languages lost their deadness." He urged others to collect like treasures and "not to be deterred from so doing because a friend in a thoughtless moment, has termed him a 'crank' or a 'mere collector!' As one grows older in the work he smilingly accepts these designations of affection."

As the collection exists to-day it bears the imprint of Dr. Smith's personality. Old engravings, aquatints, lithographs and photographs of chemists of all nationalities; autograph letters and manuscripts of the great ones—Mendelejeff, Boerhaave, Berzelius, Faraday, Pasteur, Madame Curie; books, alchemical and chemical, all gathered with loving care from the far corners of the earth, that the memory of those who have contributed to the sum total of the world's happiness and development might be honored.

This special collection is an unique and outstanding monument in the history of chemistry. When Dr. Smith passed away in 1928, it was presented to the University of Pennsylvania by his widow and endowed by her as The Edgar Fahs Smith Memorial Collection. It is used at the university to illustrate the teaching of the history of chemistry, and it is open to scholars everywhere who seek rare source material for scientific papers and other publications. Because



THOMAS COOPER, 1759–1840

ONE OF THE MOST INTERESTING AND STIMULATING CHARACTERS OF HIS PERIOD IN AMERICA. EDUCATED AT OXFORD UNIVERSITY, HE SETTLED IN THE UNITED STATES ABOUT 1795 PROFESSOR OF CHEMISTRY AT DICKINSON COLLEGE AND THE UNIVERSITY OF PENNSYLVANIA, PROFESSOR AND PRESIDENT AT THE UNIVERSITY OF SOUTH CAROLINA, HE WAS ALSO ACTIVE AS AN AUTHOR, JUDGE, PHYSICIAN AND POLITICAL ECONOMIST. HE WAS A FRIEND OF THOMAS JEFFERSON AND JOSEPH PRIESTLEY. A TURBULENT FIRE-BRAND, HE WAS IMPEACHED AS A JUDGE AND IMPRISONED AND FINED IN PHILADELPHIA FOR LIBEL OF PRESIDENT JOHN ADAMS. PHOTOGRAPH OF SILHOUETTE FROM THE WILLIAM H BROWN PORTRAIT GALLERY, 1844

of the close association of early chemistry to medicine and to physics, examples of the latter sciences are also present.

In this library modern critics might profitably peruse "A Description of New Philosophical Furnaces, or A New Art of Distilling," by Johann Rudolf Glauber, London, 1651. Oliver Cromwell wrote "This Glauber is an errant knave I doe bethink me he speaketh of wonders that cannot be accomplished." But nearly three hundred years later Ferguson in his "Bibliotheca Chemica" pronounced Glauber's work "one of the most remarkable books on chemistry of the seventeenth century." These kind words would have heartened Glauber, who was a sensitive soul and labored under fear of criticism, as is shown in the following abstract from his book addressed to all critics:

> To the Malitious Whosoever thou art, O malitious carper, marke what I say. Do not despise things unknown, for there is no man in the earth can please all . . . Truth shall remaine, when haters of truth shall perish. . . . Wherefore do not touch the innocent, that seek nothing but thy good, and shews the right way to get wealth and honour. If thou hast anything better communicate it; there is no body will hinder thee; if not bridle thy tongue, and do not carp at him that is through the blessing of God, eminent in the arts.

We handle reverently Elias Ashmole's "Theatrum Chemicum Britannicum," London, 1652. It is a compilation of verses upon alchemy and the alchemists by Chaucer, George Ripley, Thomas Norton and others—and the great Sir Isaac Newton paused to read what they have said. This volume contains the bookplate of Sir Isaac Newton, and is corrected and annotated in his hand. The name of Thomas Norton, author of the "Ordinall of Alchimy," contained herein is curiously revealed in the first word of the poem and the initial letters

AN OLD DRAWING TO SHOW EXHILARATING EFFECTS OF NITROUS OXIDE GAS.
ILLUSTRATION FROM A THESIS PRESENTED TO THE MEDICAL SCHOOL OF THE UNIVERSITY OF PENNSYLVANIA IN 1808 BY WILLIAM P. C BARTON, ENTITLED "A DISSERTATION ON THE CHYMICAL PROPERTIES AND EXHILARATING EFFECTS OF NITROUS OXIDE GAS, AND ITS APPLICATION TO PNEUMATIC MEDICINE" BARTON BECAME PROFESSOR OF BOTANY IN THE UNIVERSITY OF PENNSYLVANIA AND A SURGEON IN THE UNITED STATES NAVY.

of six following chapters, together with the first line of the second chapter.

> Tomais Norton of Briseto
> A parfet Master ye maie him call trowe.

"Elementa Chemia," by Johann Conrad Barchusen, 1718, contains beautiful symbolic plates portraying mysterious alchemical processes. In this we find marginalia of the poet, Samuel Taylor Coleridge, who is known to have had a deep interest in mysticism and the occult. On the fly-leaf he wrote:

> John Hartwell Bonsall Williams—
> Lord help you, Sir! We have not room for half of you.

Philosophies other than chemical may be found in many of the old volumes. Oswald Croll's "Bazilica Chymica," first published at Frankfort in 1608, passed through eighteen editions in fifty years, and the printed marginal notes to his "Doctrine of Signatures" contained in a translation attract us:

> The vertue of many things are unknown to us, only through our own negligence of experimenting them
>
> Many things by most learned men might be obtained, if through false Ambition they do not persuade themselves to be sufficiently learned already.

And the following initiates us, perhaps, into the secret of the luxurious growth of hair of many of the ancients:

> The Haires of a Man, if distill'd, a juyce comes forth, which used by annonyting is profitable in prolonging the Haires of the Head.

In "The Art of Distillation," by John French, London, 1653, with seventeenth century marginalia, we read an ingenious defence of alchemy:

> Did not Artefius by the help of its medicine live 1000 yeares? Did not Flammell build fourteen hospitals in Paris besides as many in Boleigne, besides churches, chappels with large revenues to them all? Did not Bacon do many miracles? and Paracelsus many miraculous cures?

And among the strange secrets revealed is one on "Luminous water to give light by night, made by distilling glow-worms' tails or herrings skins."

"De Veritate et Antiqvitate Artis Chemiae," by Robert Vallensis, Paris, 1561, is of especial interest because it is the first attempt to present a history of chemistry. The copy noted is the first edition in original covers—48 unnumbered leaves, printed in italic type by Frederick Morrell, a pupil of Aldus Manutius. We know there is a copy in the British Museum—there may be another in the United States—and we handle it with reverence that such a tiny thing should have survived and grown old so beautifully through the passing centuries.

And so we come to the apology which Dr. Smith felt called upon to make to the guild of chemists for wandering from the path of pure science into the byways of collecting.

> There are those who think and, it may be, declare that chemists ought not to dream, yet I frankly confess as I have sat gazing at a near-by old-fashioned book case, that I have dreamed—because, the higher shelves carry musty volumes which in their day did—
>
> "Fill the world with dread,
> Were much admired,
> And but little read,—"
>
> for they are old chemistries—that's all! which have gradually grown in number. Tho' seared their leaves, crude their bindings, often dreadfully worn and decayed—they recall as do old, old letters of love and story—that
>
> "Through those manifold, twinkling, sparkling pages something of the past beckons us, whispers us, delights us, and above all in the magic phrase of Keats, teases us out of thought, as doth eternity."[2]

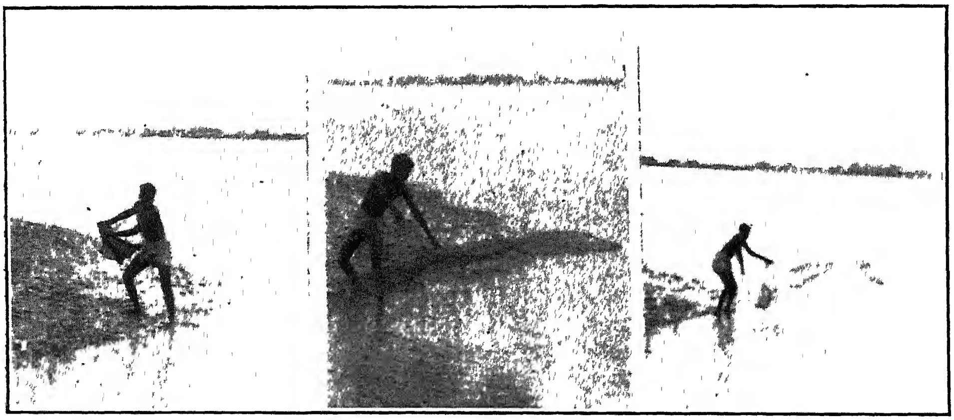
[2] "Old Chemistries," by Edgar F. Smith. McGraw-Hill Book Company, 1927.

THE GANGES DELTA

By Dr. A. S. PEARSE
PROFESSOR OF ZOOLOGY, DUKE UNIVERSITY

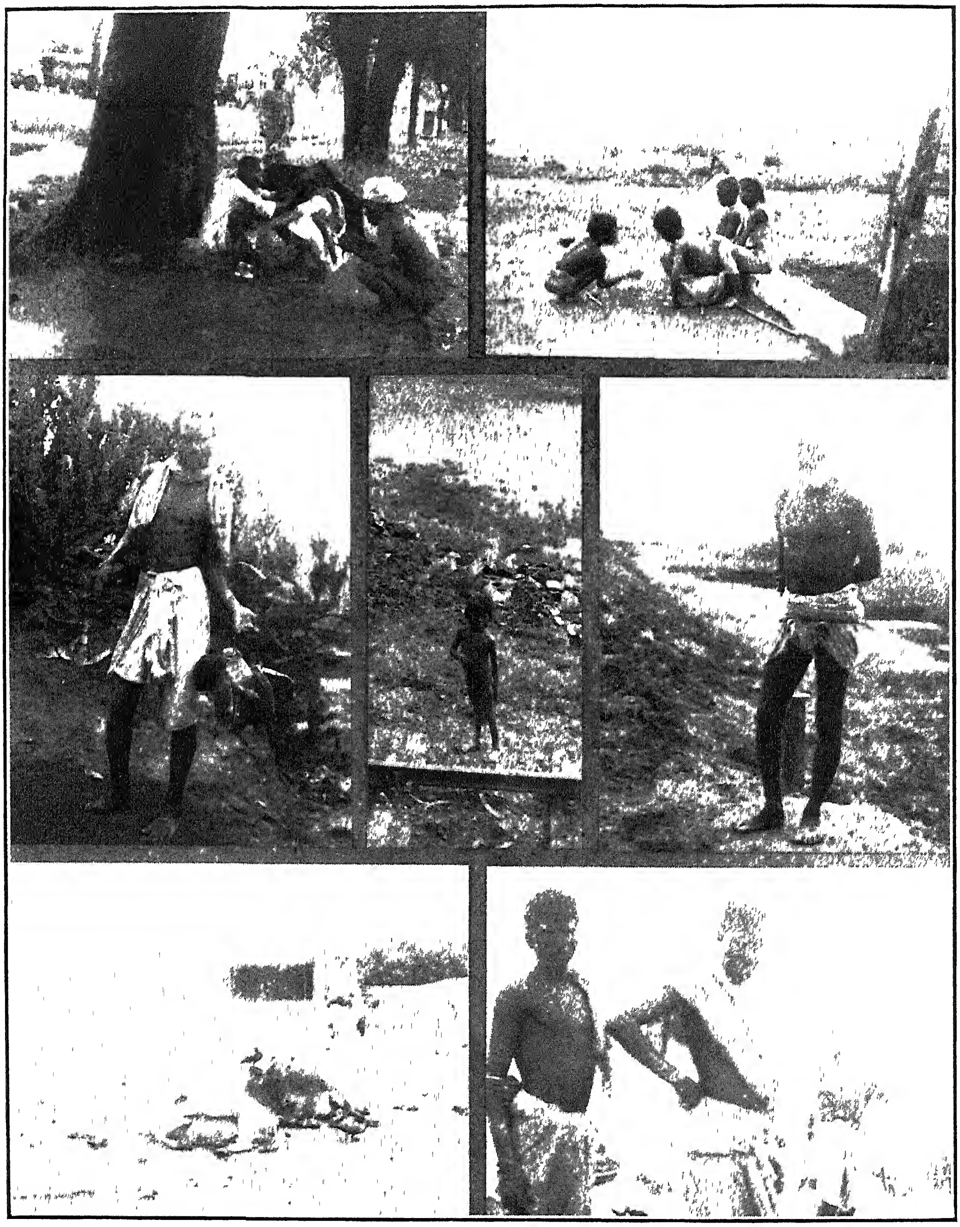
For centuries the Ganges River has been depositing mud at its mouth. From the southern border of the Himalayas and Central India the turbid waters of its tributaries carry silt past Delhi, Agra, Benares and other famous cities to deposit in its great delta, which thus continually encroaches on the Bay of Bengal. As long ago as 1840 Smith made borings to a depth of 481 feet and found alluvial deposits. From May to November it really rains south of the Himalayas. Pelseneer (1906) pointed out that the heavy rains at the head of the Bay of Bengal dilute the ocean so that marine animals there have become adapted somewhat to fresh water. But Annandale (1922), after studying the animals in the Ganges Delta for many years, was astonished that so few species were able actually to attain from the sea to the river. There are, however, a few typically marine animals which have invaded the river itself—horseshoe crabs (Limulus) are seen at Calcutta; there is a porpoise which lives in the Ganges and never goes to sea.

For many years the great Ganges Delta has allured me. What an opportunity to observe estuarine animals! In 1930 I got my chance. In Calcutta the staff of the Indian Museum was most helpful. The director, Colonel Seymour-Sewell, Sundar Lal Hora, Hem Singh Pruthi, B. G. Chopra and others proved to be most competent and agreeable gentlemen. We ate lunch together at Firpo's Restaurant. Afternoons at tea in the museum building we talked of everything from Ghandi to crabs. A rich ornithologist at the museum, Satya Charn Law, took me to his home and to his magnificent country estate where deer and pheasants lived beneath slender palms and beautiful shrubs. I was established in the Grand Hotel and soon learned to enter between the stolid Brahmin bull and the little handless beggar girl without trepidation. The Museum and the Bengal Natural History Society next door are



THROWING A CAST NET

A BACKWARD SWING, A SKILFUL WHIRL, AND THE NET FALLS OVER UNWARY FISHES IN THE RIVER BELOW.



SCENES FROM DAILY LIFE IN INDIA

Top: left, A GENTLEMAN GETTING SHAVED ON THE STREETS OF CALCUTTA, *right,* CHILDREN PLAYING JACKSTONES. *Middle: left,* A LEPER WITH TURTLES; THE TERMINAL PHALANGES ON EVERY FINGER AND TOE HAVE SLOUGHED OFF. *Center:* A GIRL BESIDE THE ROAD TO PORT CANNING; *right,* A COUNTRY SQUIRE ON A DIKE ALONG THE GANGES. *Bottom. left,* INDIAN CROWS WITH A ZEBU AND A COW; *right,* SPINNING AND WEAVING CAST NETS.

great treasure houses, not only of specimens, but of fine and antique books. Perhaps most wonderful of all are the rows of cases of Kashmir shawls, fine rugs and tapestries.

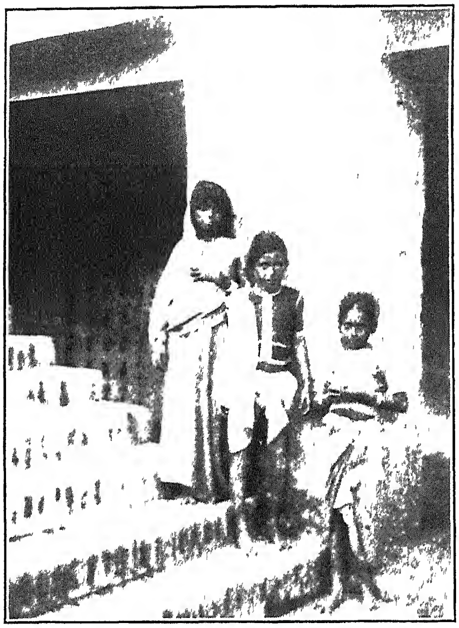
After several conferences it was decided that Port Canning would be the best place to study the Delta. The museum collector, R. Hodgart, a messenger, Ganoor; a cook, Iqussain, and an assistant cook accompanied me. Along the road to Port Canning the farmers were plowing their rice fields, knee deep in water behind patient zebus. At each station a boy walked, shouting, beside the train When signalled he deftly whacked off the top of a cocoanut and presented it to a thirsty traveler, for an anna. There was no other drink to be had.

At Port Canning the caste system made it necessary for us to hire a local sweeper to come each day, for there are some things which it is disgraceful to do, and sweeping appears to be considered about the worst of these The collector was most capable; Ganoor cheerfully waded about in mud to collect animals; Iqussain seemed to spend most of his few waking hours smoking a water pipe made from a cocoanut and a bamboo tube, but furnished most satisfactory food The Public Works Department gave me two rooms on the second story of a government bungalow From these the dike along the Malta River (one of the many mouths of the Ganges) could be seen for more than a mile All the wit and beauty of the region used the flat top of the dike as a highway and there were many curious things to see.

TWO GIRLS BESIDE A MUD WALL

WHICH ENCLOSES A MUDDY GARDEN BESIDE A MUD HOUSE.

As soon as the sun was up in the morning the landscape was dotted over with squatting citizens, who after relief resorted to the nearest body of water to wash by hand their soiled posterior ends. Immediately after them to the same waters came other men to wash their teeth, housewives to dip up water for their morning meal, and cleanly persons who desired to drive in their sheep or cattle for a morning bath. Thus the Hindoos successfully maintain disease



LOW CASTE GIRLS
WHO MUST SPEND THEIR LIVES SWEEPING, HERDING PIGS, AND IN OTHER DEGRADING OCCUPATIONS.

HEM SINGH PRUTHI AND THE WRITER
IN THE COURTYARD OF THE INDIAN MUSEUM IN CALCUTTA.

and high mortality. Except when forced by arbitrarily imposed order from a British officer, sanitation is unknown in India. During the early day a continual procession of people and other animals passed along the dike: graceful women with shining brass pots on their heads; sturdy fishermen spinning or weaving nets as they walked; slow feeble lepers, plodding sufferers from elephantiasis with gigantic limbs or genitalia; laughing, more or less naked children; goats, sheep, pigs and cattle. During the heat of midday there was little traffic. At night it became active again. I then sat alone on my portico, the only white man for many miles, and felt lonesome. There was no light for reading or writing. Great fruit bats two feet long flitted past like evil spirits to engage in their nocturnal robberies. And it rained, sometimes drizzled and sometimes poured, but always rained. I went to bed.

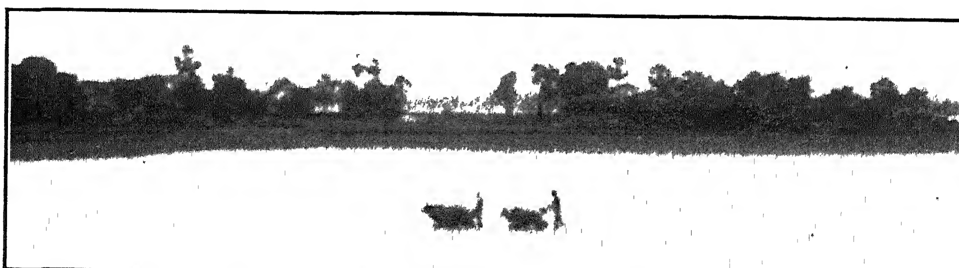
Along the side of the dike next to the river there was an interesting group of animals not only in the river itself but in rather definite zones through the twenty feet between low- and high-tide marks. Among the common inhabitants of the water was the fish, *Aoria gulio* Hamilton-Buchanan, three air-breathing fishes which will smother if kept under water—*Ophicephalus striatus* Bloch, *O. gachna* H.-B., *Saccobranchus fossilis* H.-B.—and a strictly aquatic goby, *Glossogobius giurus* H.-B. In the mud near low-tide mark lived two slender little fishes (*Apocryptes lanceolatus* Bloch and Schneider; *Tanaeoides rubicundus* H.-B.) in burrows. They rested with heads at the mouths of their burrows and snapped up small animals carried by passing currents. Above these beach-skipping gobies rambled about over the mud (*Periophthalmus* sp.). These active fishes have protruding eyes and see well in the air. They catch small animals, as worms and insects, in such a way that there is no doubt that they see

ON THE HOOGHLY RIVER
ONE OUTLET OF THE GANGES

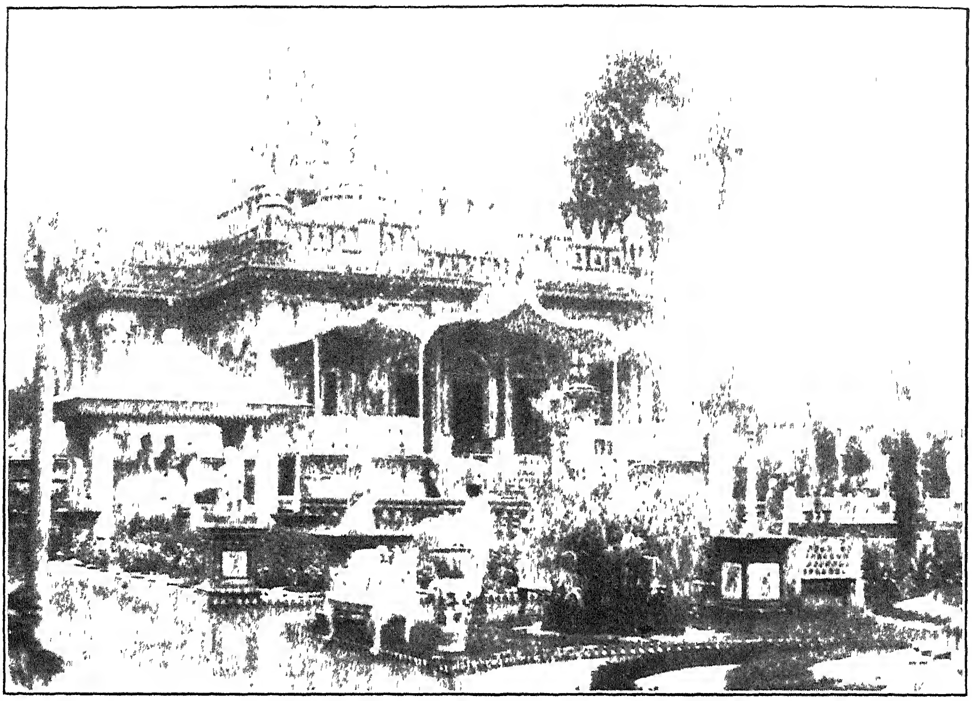
them well from a distance of several feet The ventral fins of these gobies form an adhesive disk which enables them to climb up vertical surfaces.

Crabs, like the fishes, are arranged in zones along the dike. A hermit crab (*Clibanarius padavensis* de Man) wanders over the mud near the water, and a great swimming crab (*Scylla serrata* Forsk., de Haan) forages. The gill chambers of the latter are commonly infested with little commensal barnacles. On the mud flats two crabs, *Dotillopsis brevitarsus* (de Mann) and *Metaplax dentipes* (Heller), scurry about or bury themselves in the mud. Near high-tide mark there is an active hermit crab, *Uca manni* Rathbun, which, like the beach-skipping gobies, feeds only out of water, but never builds burrows far from the river, for it must carry water in its gill chamber. However, another crab, *Sesarma taeniolatum* White, lives continually above high-tide mark under rubbish and breathes air. Two crabs, *Parathelphusa spinigera* (W -M) and *Varuna litterata* (Fabricius), live in the river and in neighboring fresh waters, often at some distance from the river itself. The former is an estuarine species and the latter is a proper fresh-water crab which has no close marine relatives.

In any estuary there is a struggle among animals which are trying to spread to new habitats; an eternal struggle which has been going on almost since life and habitats began. With an open highway and a graded series of salinities it seems strange that so few animals have been able to leave the ocean and enter rivers; or move from rivers to become established in the ocean Of all the fishes known, less than twenty-five species migrate freely from sea to river. Ichthyologists and paleontologists maintain that bony fishes originated in fresh water All marine teleosts have therefore become adjusted to life in the ocean, but it has taken a long time. A few insects and mites have left the land to live



WHEN A HINDOO PLOWS HIS RICE FIELDS
HE WADES IN WATER UP TO HIS KNEES.



THE PARESNAT TEMPLE IN CALCUTTA

in the ocean. Annandale (1922) believed that of the some hundreds of animals listed by naturalists from the Ganges River only about ten had clearly come from the ocean.

Along the shores of the Malta River each animal has spread into its appropriate niche and seldom is able to go farther. Some types are not able to leave the sea because they lose salt from their blood. Their external membranes can not maintain the internal fluids in such concentration as to permit body cells to live Others are turned back by enemies or competitors. Some animals from estuaries migrate into fresh water each year but are unable to breed there. It is more difficult for an aquatic animal to breathe in fresh- than in salt-water The salts in the ocean actually make respiration easier. Burrowing animals in tidal areas have protection underground from desiccation when the tide falls, but only rarely in the past have they been able to attain life on land.

So the struggle goes on in the Ganges Delta. On the fertile land people struggle against exploitation by propagandists who tell them that Ghandi will give them free food, clothes and idle ease when India is independent, against terrible age-old traditions of caste, dogma and ignorance; against cholera, plague, elephantiasis and other diseases; struggle to live and increase. In the hydra-head of the river animals struggle to hold their own and are eternally striving to spread into new habitats where they may perhaps find peace, quiet and food. But usually species are put rather definitely in their places by nature. Each animal comes into existence with a definite range of tolerations to variations in environment. Where millions try to attain new things, one may succeed.

CEREALS AND CIVILIZATION

By MORRIS HALPERIN

COLLEGE OF AGRICULTURE, UNIVERSITY OF CALIFORNIA

The Nomadic Life of Early Man

Primitive man lived by wandering on grasslands as a hunter of the grass-eating animals which constituted probably his sole food-supply.

The hunting stage of early man's life was followed by that of grazing, in which man domesticated the horse, ox, sheep, goat, pig and dog and made a somewhat settled abode for himself and for his animals on one or another favorable piece of grass-land. However, occasionally there would be a year of great drought in which the grass "crop" was a total failure, with the result that the animals had no feed and would perish. The perishing of the grass-eating animals reduced man's food and compelled him to wander with his surviving cattle in search of pasture. That type of life was very uncertain—people did not know when a drought would dispossess them from their abode and not always would there be another abode to go to.

Grass Cultivation: These successive stages of hunting and grazing then "evolved" into the third scene of the agricultural melodrama, namely, the cultivation of the cereal grasses—those grasses which man found to be good food for himself. The grain of one harvest could be *stored* until the sowing time of the next season or even for a few seasons. This carry-over of grain tended to offset the ravages of drought. The result was that man could stay in one place more or less permanently and thus obtain a portion or even all of his food supply direct from the cereals, or else could carry the grain with him anywhere he desired and sow it there.

It was thus that cereal-raising, the earliest form of agriculture, was spread to other localities which trial-and-error methods showed to be suitable environmentally for the cultivation of the various cereals. Human life changed from that of wandering to that of settling-down. Man changed from a mere food-gatherer to a food-producer, and from the purely meat diet of the hunting stage to the mixed meat-and-grain diet in the era of agricultural cultivation with all that that implied of tillage, ecology and even plant-breeding.

Cereals, Leisure and Civilization

The tremendous importance of this change was that in every place where cereal-cultivation became established civilization set in; and, stated conversely, history has no record of any true civilization which developed without cereal-production as its basis.

When people wander, as do the modern Baktyari and other tribes, it is a practical impossibility to "settle down." The essential point in this whole regard is that the insurance of a food-supply, which the raising of cereals, entirely or nearly so, brought about, provided leisure. That is the keynote for any mental or spiritual progress that has ever occurred in any people. It is in this leisure of early man that we see the beginnings of art, of science, of language and literature, of social life, indeed of thinking itself. Moreover, cultivation of land permitted the conservation of the energy formerly spent in roaming; it led to a sense of ownership of land (with the consequent interest in improving it), and to the continuous development of metallic tools and appliances for so doing. In general, the cultivation of cereals made it both necessary and possible for man's civilization to begin and

to continue, as can be seen by a study of the history of man in all parts of the world, from prehistoric times down to the present.

INDIAN CORN IN AMERICAN CIVILIZATION

On the entire American continent, from Canada in the north to Patagonia in the south, the existence of the people was virtually synonymous with the cultivation of one cereal, *viz.*, maize or Indian corn.

Maize among the North American Indians

To the American Indians, maize was a miraculous gift from the gods. In one well-known version, Hiawatha yearned that his people might have a more sure source of food than was provided by hunting and fishing. The answer to his fervent prayer was Mondamin, whom Hiawatha overcame and buried and from whose grave emerged maize, the ever-dependable food for Hiawatha's people.

Nearly all the other Indian tribes had one or another myth regarding the origin of their great food, the maize plant. It was the American Indian, by his keen "field selection," who developed maize to its present rank of being the most highly specialized grass in existence.

In the Great Lakes region, the Indians lived largely on maize, but in addition they gathered wild rice (also called Indian rice) growing in wet "land" through which the squaws traveled in canoes, tied an armful of the plants together just below the heads, allowed the bundles to ripen, and returned later to "thresh" the grain by beating the tied heads over their canoes.

Amongst the Iroquois, the marriage contract was celebrated by a ritual in which the bride brought two maize cakes to her prospective mother-in-law.

The Mannharis had a harvest celebration in which the dancing women represented the ripe and swaying maize-plants; the men represented the reapers of the crop and the plowers of the field.

The Osage girls expressed their desire for marriage by giving their fiancé a piece of maize bread.

The Modern Hopi and Papago Indians

In their extreme isolation in northeastern Arizona, the modern Hopi Indians are still very primitive in their agricultural practices. The Hopi have very few tools and they practice little or nothing of modern farming in their cultivation of grain. When the maize is harvested, it becomes the property of the housewife, who has learned, through sad experience, that she must carefully store away enough maize to tide her family through at least the next year of possible drought. She watches diligently for weevils; when she spies any she calls in her woman neighbors, who together form an inspection squad, giving every ear of maize the "once over"; any weevils which are so unfortunate as to be detected and captured are ceremoniously removed and "humanely destroyed." The housewife prepares maize in an epicure's variety of ways. A special occasion is the ear-roasting outdoor picnic, at which the farmer and his family assemble with their friends and have a happy time feasting on ears of maize roasted in the fire.

The Papago Indians, who live on a reservation near Tucson, Arizona, are experts in dry-land farming. They raise maize and Sonora wheat from which they make their native breads. Some of them mix wood-ashes with their wheat seed before sowing; and when asked for the reason for adding the ashes, they merely say, "It is good!" The Papago threshes wheat by the ancient method of preparing a "floor" on which he lays the wheat. Then he adds his own method of driving several ponies over the wheat, a process "catalyzed,"

no doubt, by the abundant perspiration (and probably other exudates) from the body of the animals. When the appetizing threshing is over, the grain is winnowed by being thrown in the air. The surplus grain is stored in a granary made out of coarse grass.

The Ancient Mexicans

The civilization of the Aztecs (the partial ancestors of the modern Mexicans) was also based on maize. Several varieties of this cereal formed the chief part of the diet among the Aztecs. The maize grain was made into bread and pancakes and porridge. The Aztecs' chief beverage was made by fermenting the grain or stalk of maize.

After certain religious ceremonies, the girls crowned themselves with chaplets of maize. In their idol-worship feasts, a long cord ornamented with grains of dried maize strung on threads into the form of a wreath was placed around the esteemed idol. For periods of four years, penitent and austere priests lived on a daily ration of a small loaf of maize bread and a cup of "stolli," which was a sort of soup made also from maize. In periods of public calamity, the high priest of Mexico lived for one year on raw maize and water.

The Maize Civilization of the Mayas

Among the Mayans, in Mexico and in Central America, maize formed the basis of nearly every dish. Large balls of maize were preserved dry for several months and were eaten dry or, for a beverage, were broken up and mixed with water. The Mayas made "hot cakes" by compressing ground-up maize-grain and heating the exuding juice until it curdled.

All the Mayan religion was featured by maize. For instance, in their story of the creation of the earth, maize was the material from which the three "Creators" made four men who later, when asleep, gave rise to four women, thus beginning the Mayan race! In the elaborate ceremony which the Mayas practiced in baptizing their children, incense and a few grains of maize were the indispensable substances employed. They worshiped chiefly the maize god, the lord of the harvest fields, whom, however, from sad experience, they always depicted as being himself dependent upon the gods of rain and drought. At their religious sacrifices and New Year's ceremonies, maize cakes and maize loaves were very prominent. At a burial, a few grains of maize and some stone money were put into the mouth of the deceased (the maize kernels were apparently to be the corpse's means of subsistence until he reached the next world, and the money was intended for the purchase of provisions after he arrived there).

In the ordinary life of the Mayas, there was only one important activity which did not involve maize: The mothers used a stinging pepper to rub the bodies of their disobedient children to punish them. Except for this, the maize plant constituted the chief article in the existence and life of the Mayas.

It should be added, however, that the production of maize year after year on the same land is considered to be one of the causes for the downfall of the Mayan civilization. The failure to use other plants in a system of crop-rotation resulted in depleting the fertility of the soil and, eventually, probably led to the failure of agriculture and ultimately (in this particular case) brought about the death of the very civilization to which it gave birth.

Among the Caribbeans, the young man brought the prospective father-in-law some maize bread with which to celebrate the marriage.

The physical existence and the social and religious life of the Pueblos, Guatemalans, Incas and Peruvians were also centered upon maize.

From diaries and other records it is learned that the early settlers of the present United States brought seed of rye, wheat, oats and barley with them from Europe and planted these for crops as early as 1625—crops which, by 1925, were amongst the most valuable products in the country.

Maize in South America

Along the Orinoco River, the Wapishana and other peoples grow rice, introduced probably from the East Indies, which they use in addition to the maize growing wild there. Throughout the Guianas, maize is the staple crop and the dietary mainstay. The Otomac Indians there grow a variety of maize which they call "two-months' maize" (mais de los mesas) because this variety requires only two months for its complete "life cycle" from sowing to harvesting and thus yields six crops a year.

The Makusi of the upper Cotinga make bread from a mixture of manihot and maize meal as well as pap made of pounded maize boiled with cut-up pumpkin. On the Curiebrong there is a product called "aknaikh," a mixture of maize and buck-yam pounded together with a mortar and pestle. These South American people make a fermented maize drink which is quite popular. Maize, ground with the vigor of a woman's arms, is made into loaves called "cayzu." These are allowed to stand from fifteen to twenty days when they become covered with mold, which is yellow on the elevated plains and green on the warm lands. Thereupon they are christened "subibzu," crushed to powder and mixed with a large quantity of hot water to which sugar is sometimes added. The product is strained and collected in large earthen jars, where it effervesces on the third day, the resulting beer being considered a healthful drink and a close competitor of the alcoholic products of cassava.

Outside of the Western hemisphere (North, Central and South America), wild maize is not found. In the Eastern hemisphere there are other grains, each of which has exerted a dominating influence in the initiation and the development of human life.

CEREALS IN AFRICA

The Great Egyptian Civilization

On the African continent we find one of the world's oldest civilizations, that of the Egyptians. Barley has been found in Egyptian pottery jars dating from 4000 B.C. Millet too was cultivated at that time.

Wheat has been found in the bricks of the Dashur pyramid, which was built before 3300 B.C. Wheat has also been found in the Nile Valley, in the oldest known graves in the world. Wheat chaff, being easily removed from the grain before the making of the bread, is not found in the stomachs of bodies from these earliest cemeteries; the chaff of barley and of millet, present in the bread, is, however, found in these graves. Sorghum has been grown in Egypt since primitive times, but no remains of it have been found in these tombs.

The Egyptians considered wheat a gift from Isis, the principal Egyptian goddess, who originated agriculture as well as the arts which accompanied agriculture and who symbolized fertility. In the Egyptian "Book of the Dead," King Osiris states: "I am Osiris. I live as Grain. I grow as Grain. I am Barley." In Egyptian literature there are poems which mention "barley, wheat, and fruit trees," probably indicating the order in which these were important. Apparently the Egyptians, although only mild imbibers, were held by others in contempt for their intemperance, for in one of the poems of Aeschylus a king of Agros assures the Danaids who had just come from Egypt that here they "will find a manly population and not

drinkers of barley wine." Rice is an ancient crop in Egypt, whence it came from India. The beginning of the "evolution" of the modern plough was the hoe used in Egypt in the growing of barley.

Cereal Astronomy and the Cereal Calendar

The Egyptians were the world's first astronomers. Their interest in astronomy was motivated entirely by the desire to watch the movements of the moon, in order to notice its effect on sowing and on the other steps in cereal-raising.

Closely associated with the interest which the Egyptians had in astronomy was their priceless contribution to civilization in the form of the calendar. In the nomadic life of primitive man, the day was for hunting and the night was for sleeping. But the settled abode which came with cereal cultivation made it very desirable to keep a record, largely on the basis of the moon's activities, as to when it had been found best to sow and irrigate and perhaps fertilize the growing grain. By doing the various steps in cereal production during certain "months" and on a certain number of days after the "new moon," the chances for success were improved greatly over haphazard agricultural activities.

The earliest dated event in history is the establishment, in 4241 B.C., of the Egyptian calendar of twelve months of thirty days each, plus five feast days. One month was called "Sprouting of the Grain" and others were called "Making and Watering Barley," "Ripe Grain," "Lady of the Granary" and "Grain Gods"—all these indicating markedly the agricultural necessity for, or desirability of, the calendar, an invention which passed by way of the Babylonians, Greeks and Romans to the modern peoples of the Christian era.

The Two Great Papyri

Very intimately associated with both astronomy and the calendar among the Egyptians was obviously mathematics. This great science too developed out of the necessity for calculations relating to cereal production.

The present scientific knowledge of Egyptian mathematics is contained in two papyri, the Rhind papyrus and the Golenishchev papyrus. In the Rhind papyrus, written about 1650 B.C., problems 41 to 46, inclusive, deal with the dimensions and volumes of cylindrical and parallelopipedal granaries, showing that the necessity of storing surplus or reserve grain for the next year of possible drought spurred on the Egyptians to find the shape of a granary which would hold the largest weight of grain for its volume. It is in these problems that is found the first Egyptian record, copied from the Golenishchev papyrus of about 1850 B.C., of the value for π of 3.1605, a very close approximation to its true value of 3.1416.

The Rhind problem 64 is one involving arithmetic progression:

> Distribute 10 hekat of barley among 10 men in such a way that the shares shall have a common difference of $\frac{1}{8}$ hekat. What is the share of each?

Problem 69 reads:

> $3\frac{1}{2}$ hekat of meal are made into 80 loaves of bread. Let me know the amount of meal in each loaf.

Problem 79 is very interesting:

> In each of 7 houses are 7 cats, each cat kills 7 mice, each mouse would have eaten 7 ears of spelt, each ear of spelt will produce 7 hekat of grain; how much grain is thereby saved?

In the Golenishchev papyrus, 10 out of the 25 problems pertain to the so-called pefsu or cooking-ratio of grains comparable to the modern "calories" of various foods.

Other African Cereals

Over large areas of Africa outside of Egypt, particularly in the Sudan, another cereal, sorghum, was the center of the people's existence. In Ethiopia, millet and barley were used for food and beverage. In tropical Africa, two other grains, teff and fundi, were the chief element in the diet. Amongst the Negroes in the Sahara, after the marriage contract has been closed, the man gives the bride's parents 60 liters of grain, a rich present in that district.

When a woman of the Nilotic Kavirondo tribes gives birth to a boy-baby, a stalk of Kafir sorghum is pulled out of the roof of the hut on the right side of the fireplace (looking from the hut outwards); if a girl, a stalk is pulled out from the left side.

The present names of sorghum varieties, such as kafir, milo, durra and feterita, used in the United States are African names.

CEREAL CIVILIZATION IN ASIA

On the vast Asiatic continent, we find most of the world's earliest civilizations, all of which were made both possible and necessary by the cultivation of one or another of the cereal grasses.

Rice in Chinese Civilization

If not the very earliest, then one of the earliest known civilizations arose in China, where it developed around another cereal, rice, one of the oldest plants cultivated by man.

The cultivation of rice gave the Chinese not only a sense of settled life and a relatively dependable food-supply, but brought them in contact with the soil and eventually with all nature. The ancient Chinamen learned that rice would grow only with irrigation, so that it was necessary to build levees, dykes, canals and elaborate terraces. These extensive mechanical and architectural changes could be made only by the whole community, so that social life and amicableness towards neighbors inevitably resulted. These changes also brought about *leisure,* which, in turn, provided opportunity for philosophical meditation and for literature. The same changes in the soil tied the Chinese still more to the land and made it precarious to engender wars with neighboring peoples in which they might be driven from their "homes" built up by long and expensive work. The strong sense of ownership which was produced by these improvements, and the normal surety of obtaining a cereal crop, doubtless favored an increase of population and eliminated aggressiveness on the part of the Chinese. There seems to be a definite agricultural basis for the personal characteristics traditionally associated with the Chinese.

Sorghum spread from Africa to China, where it became known as kaoliang, meaning "great millet," and it retains this name to-day even in American agriculture. Millet was cultivated since prehistoric times in China and spread from there westward to Europe, where it became known as Italian and German and Hungarian and Foxtail millets. In northern China, wheat was and is grown extensively.

In 2700 B.C., the Chinese Emperor, Chen Ming (Shennung), instituted the symbolic ceremony of sowing five useful plants each year. Those crops were rice, wheat, sorghum, millet and soybean, all of which, except the soybean, are cereal grasses. Rice, being the chief plant in the ceremony, used to be sown by the Emperor himself.

Cereals in Other Eastern Asiatic Civilizations

In Japan, rice has been grown since primitive times and still is the most important crop grown there. Millet too has been cultivated in Japan before the time of historical record.

In the Indian Archipelago, rice and

millet were cultivated since prehistoric times, the plants themselves bearing mute testimony of a long history of cultivation.

In Borneo the female Dayaks use a pot of rye to conceal an object of one kind or other whereby they indicate, in a modest tribal manner, the men whom they would like for their respective husbands.

Rice spread, probably from India, to the Malay Peninsula, where it became and has remained the dominant crop. In the Philippine Islands, too, rice became dominant, and it is cultivated there to this day on hillsides which are very skilfully terraced so as to hold rain and prevent runoff.

Rice and Barley among the Aryans

In India, rice was cultivated since nearly prehistoric times. Rice spread from India eastward and westward and southward to other parts of Asia. Sorghum and pearl millet spread into India from Africa. The cereal coracan is native to India.

The civilization of the Aryan cult in northern India of about 1500 B.C. was based chiefly on grains. Food consisted primarily of rice, which was husked by slave girls, and of barley, which was ground into flour and made into bread. A beverage called "sura" was made by distilling either barley or rice. To their gods, the Aryans offered up roasted barley and cooked rice; the person who cooked the rice, it was firmly believed, would not bear harm at any time but would be world-conquering and heaven-going! A baby when cutting its first teeth was fed on rice or barley. An "inherited" disease prevailing amongst the Aryans was dispelled by having some one wave "a straw of barley, tawny brown, with its silvery ears" close to the afflicted individual.

The Persians cultivated wheat as the chief constituent of their diet. Rice was entirely unknown in Persian (Iranian) antiquity; it is only since the time of the Arabs' conquest (7th century A.D.) that rice has been grown in Persia.

Babylonian Cereals

In the earliest Babylonian calendar, the names of six of the twelve months refer to the cultivation of grain and the names of two other months refer to the eating of grain, indicating the agricultural origin of the calendar. The tablet of Enkhegal, of about 3100 B.C., one of the oldest Babylonian inscriptions, states that land was paid for by bronze and by grain. By 1300 B.C., there was an appliance for plowing the land and sowing the seed of grain in one operation. Concerning Babylonia, the historian Herodotus, the "father of history," wrote in 450 B.C.: "The soil is peculiarly adapted to grain; no wine, olive, fig or other fruit trees are grown; only barley, wheat, and millet are grown."

The king of Iberia, in his palace, had golden and silver vessels filled with barley juice for use as a refreshment.

The ancient Armenians used millet for food and for drink.

The Syrians cultivated largely rice, which spread to Syria from India.

Cereals in the Holy Land

Another important Asiatic civilization was that of the Hebrews, concerning whom we learn a great deal from the Bible.

Joseph, in his first dream, saw his brothers' sheaves of grain (probably barley) in the field, bowing to his sheaves (Gen. 37: 7).

Pharaoh's second dream pertained to "seven ears of corn (doubtless barley) upon one stalk, rank and good" and "seven thin ears . . . blasted with the east wind" (Gen. 41: 5–7). The famine which soon followed was a dearth of grain; only in Egypt, by Joseph's advice, was the grain stored in huge quantities.

At the time of the plague of hail upon the land of Egypt, "the flax and the barley were smitten; for the barley was in the ear, and the flax was bolled. But the wheat and the rye were not smitten; for they were not grown up" (Ex. 9: 31, 32), indicating the Hebrews' knowledge of the relative order of maturity that pertains, in general, for these cereals in most other parts of the world to this day.

Moses, when leading the Israelites into the promised land, told them the rewards of obedience: "He (God) will give you the rain of your land in due season, the first rain and the latter rain, that you may gather in your grain and your wine and your oil" (Deut. 11: 14), the grain being mentioned first doubtless because of its eminence.

Wheat and barley are mentioned as indispensable parts of many of the offerings and sacrifices mentioned in the Old Testament.

Naomi, the Jewess, and Ruth the Moabitess, her daughter-in-law, "came to Bethlehem in the beginning of barley harvest." When Ruth gleaned in the harvest-field, she followed her mother-in-law's advice in that she "kept fast by the maidens of Boaz to glean unto the end of barley harvest and of wheat harvest." After the harvest, Naomi spoke to Ruth concerning "Boaz of our kindred with whose maidens thou wast. Behold he winnoweth barley to-night in the threshing floor." It was there that Ruth appeared to Boaz "after he went to lie down at the edge of the heap of grain" of which, before morning "he measured six measures of barley and laid it on her, and she went into the city."

When King Solomon needed lumber for the house which he "determined to build for the name of the Lord and an house for his kingdom," he wrote to Huram, king of Tyre, saying:

"And, behold, I will give to my servants, the hewers who cut timber, twenty thousand measures of beaten wheat, and twenty thousand measures of barley, and twenty thousand baths (about one hundred and eighty thousand gallons) of wine and twenty thousand baths of oil" (2 Chron. 2: 10). Here again the grains are given first rank; and, be it noted incidentally, the wheat was "beaten" while the barley, with its adherent chaff, was not!

The prophet Joel, when speaking to the Jews of their poverty, says: "Be ye ashamed, O ye husbandmen, weep, O ye vine-dressers, for the wheat and for the barley; because the harvest of the field is perished" (1: 11). Apparently even the grape-growers depended upon grain for their mainstay, for they were exhorted to lament for the failure, not of the vintage but of the grain-crop!

The good and patient Job, in his grief, asserted that if he had ever taken aught that was not his, "Let thistles grow instead of wheat and cockle instead of barley" (31: 40).

In "The Book of Jubilees," a Judaistic work of the second century B.C., it is stated that Abraham made an implement for sowing and plowing in one operation, in order to "keep the grain-seeds out of reach of the ravens sent by Satan to devour men's crops."

In the impending shipwreck during Paul's journey to the assembly at Rome, it was found necessary, in order to lighten the ship, to cast out the cargo of wheat into the sea (Acts 27: 38).

Rice is mentioned in the Hebrew Talmud, although not in the Scriptures.

It was in The Holy Land, on Mount Hermon, in 1906, that Aaron Aaronshon discovered a wild emmer-wheat, which is presumed to be the "ancestor" of cultivated wheat.

CEREALS IN EUROPE

The dwellers in the Swiss lake-villages of the Stone Age, about 2000 B.C., cultivated barley, wheat and millet.

Barley, wheat and millet were grown at the same time (about 2000 B.C.) in northern Italy. Millet has also been found in the remains of the lake-dwellers of Varene. The Arabs introduced rice culture into Italy and elsewhere in Europe, when they invaded that continent in the 7th century A.D. Probably about a thousand years later, maize was introduced from America to Italy, where it became established and has remained to this day the basis of a porridge which forms the usual dish of the peasants.

The lake-dwellers of Lombardy cultivated wheat. In what is now Hungary wheat was cultivated during the Stone Age. In Thrace (ancient Hungary), barley and millet were used for bread and beer. Barley has been found in the remains of the lake-dwellers of the Bronze age at Savoy.

When the Macedonians invaded Asia, they became familiar with rice, barley, wheat and millet, all of which they introduced into Greece. They were so fond of the cereals that they considered even oats in their grain-fields as a weed!

The Wallachians used maize, which they imported from America, to make "mamaliga," a dish still used by their modern descendants, the Roumanians.

In Germany, maize is called "walschkorn." A millet is also commonly used in Germany to make a mush called "brei," and in German little readers for children, there is a story of the "breipot" (the pot of millet mush) which floated down the Rhine.

In Holland, the Friesians have an old saying,

> As long as the breipot
>   Yields ought to the spoon,
> Occasion for sorrow
>   Will not be so soon.

The Lithuanians, Celts and Gauls also used millet, at least a sort of beer made from it. The Numantians (in what is now Spain) ate wheat and other grains and drank beverages made from these cereals. In Illyria, barley and millet were used for bread and for beer.

Russia is the home of rye. A Russian proverb says: "Bread ours, mother ours." The Ukraine region of Russia is the region from which came the earliest "hard-winter wheats," now grown extensively in improved varieties in the Kansas wheat belt.

The Great Finnish Epic

Barley has been immortalized in the Kalevala, the grand pagan epic-poem of Finland. In the very Proem (Prologue), the writer says (in J. M. Crawford's English translation):

> Let me sing an old-time legend,
> That shall echo forth the praises
> Of the beer that I have tasted,
> Of the sparkıng beer of barley.

Rune (chapter) II, entitled "Wainamoinen's Sowing," tells how

> Wainamoinen, wise and ancient
> Brings his magic grains of barley,
> Brings he forth his seven seed-grains, . . .
>
> Thence to sow his seeds he hastens,
> Hastes the barley-grains to scatter, . . .
>
> On the morning of the eighth day,
> Wainamoinen, wise and ancient,
> Went to view his crop of barley,
> How his plowing, how his sowing,
> How his labor were resulting;
> Found his crop of barley growing,
> Found the blades were triple-knotted,
> And the ears he found six-sided.

Rune XI, "Lemminkainen's Lament," tells how the Sahri maiden would not go to Ehstland because she would

> Hunger there and feel starvation;
> Wood is absent, fuel wanting,
> Neither water, wheat nor barley,
> Even rye is not abundant!

Rune XX discusses "The Brewing of Beer."

> Beer arises from the barley,
> Comes from barley, hops, and water,
> And the fire gives no assistance.

Then follows a great tribute to their wonderful beverage:

Great indeed the reputation
Of the ancient beer of Kalew,
Said to make the feeble hardy,
Famed to dry the tears of women,
Famed to cheer the broken-hearted,
Make the aged young and supple,
Make the timid brave and mighty,
Make the brave men ever braver,
Fill the heart with joy and gladness,
Fill the mind with wisdom-sayings,
Fill the tongue with ancient legends,
Only make the fool more foolish.

Cereals in Roman History

In Roman history, cereals played an important part in the agriculture and in the life of the people.

Columella gives calculations showing the amounts of grain to be sown upon areas of certain size. He gives other calculations showing the labor requirements for the various operations in producing wheat—an interesting forerunner of an important factor in modern farm-accounting. Columella mentions a millet which, with milk, forms a kind of porridge "not to be despised," and states that barley mixed with wheat makes good bread. In his time the Romans used to add chalk to their flour, in order to enhance its whiteness. Columella reports that animals thrive better on barley than on wheat. An inebriating beverage named Zythum, evidently a beer of some kind, known to be made from barley, is also mentioned by Columella.

Pliny describes the cultivation for human food of wheat, rye, oats, sorghums and millets. He gives directions for the preparation of Polenta, a porridge made from barley, which, being a very strengthening food, was fed to the Roman gladiators who were therefore called *hordcari* (from *hordeum,* the Latin word for barley).

The first reapers in Rome were invented in connection with the harvesting of grain—a reaping hook which consisted of a large and hollow frame armed with teeth and supported on two wheels, and driven through the grain so that the heads tore off and fell into the frame.

Varro noted that barley is better than wheat on dry land, and that the reverse applies on wet land—a difference which is still generally true.

In the feeding and fattening of birds, which was a very important dish with the ancient Romans, the birds' food was barley meal mixed with water, given sparingly at first and increased gradually, and, in some cases, a little wine added.

Horatius at the Bridge

Lord Macaulay's lay entitled "Horatius" relates how

LVII

Alone stood brave Horatius,
But constant still in mind;
Thrice thirty thousand foes before,
And the broad flood behind.

For the grand and heroic stand which Horatius made, his reward was that

LXV

They gave him of the corn-land,
That was of public right,
As much as two young oxen
Could plow from morn till night;
And they made a molten image,
And set it up on high,
And there it stands unto this day
To witness if I lie.

The Romans used grain to honor not only their heroes but also their gods. In fact, they had a goddess, Ceres, in whose honor were held grain festivals called Cerealia, whence our English word "cereal," the subject of this article.

SCIENCE SERVICE RADIO TALKS

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AMERICA'S EARLIEST MAN

By CHARLES AMSDEN

SECRETARY OF THE SOUTHWEST MUSEUM, LOS ANGELES, CALIFORNIA

We read of people flying across the Pacific Ocean, yet I can't remember any one walking across it. If I had to choose, I'd seriously consider walking, because the distance is only about fifty miles. You go up to the northwest tip of Alaska and there, fifty miles away across shallow Bering Strait, is the eastern tip of Siberia. In summer you'd probably find Eskimo paddling back and forth in their skin boats, while in winter the strait is often choked with ice, which you could scramble over dry-shod. This is the road by which many plants and animals got from the Old World into the New. So we shouldn't think of the two hemispheres as separated by vast oceans, but rather as joined firmly together beneath that little strip of ocean called Bering Strait, with plants and animals and men going back and forth since long ages past. Yes, men too; they follow the animals, just as the Indians followed the buffalo herds up and down the Great Plains.

Now you think I'm launched on one of those scientific pipe dreams of the Sunday supplement, don't you? Well, let me sketch a bit of the evidence so you can decide the matter for yourself. Plants and animals have ancestors, earlier and simpler forms of which they are the remote descendants. Often these ancestral forms are miraculously preserved: ferns in coal, fishes in limestone, elephants in frozen bogs, are familiar instances. So we can trace the family tree of many plants and animals, and we know that some are natives of America, others of Asia, a long time back.

The human animal has a long ancestry, too, which can be traced down the corridors of time like the others. You've heard the names Java Man, Heidelberg, Neanderthal and various others. Each is an ancestral form, an actual specimen of the human race at a certain point of its long evolution from the family of the great apes down to that of modern man. Some of them are hardly more than apes; others are little less than modern men. Where were these troublesome old gentlemen found; in America? No, not a single one of them. All are from the Old World. Only the modern types have been found over here. None of the great apes ever lived in America. So what must we conclude? Answer it for yourself.

That's going a long way back for our evidence; suppose we look for ancestors less remote. Well, there are only three great races or physical divisions of humanity in the whole world to-day, as every one agrees. They're the Caucasian, the Negroid and the Mongoloid, or white, black and brown. Asia is the home of the Mongoloids, so if the American Indian came from Asia across Bering Strait he should be one of that group. Sure enough, he is. He has in some degree every outstanding characteristic of that race. I'll mention only a few that we can all appreciate: complexion, shape of face, slanting eyes, color and texture of hair. Most convincing of all is a curious peculiarity of the upper front teeth. In 85 per cent. of the Mongoloids these teeth have incurving edges, shaping them like a shovel. The Indians have them, too.

So we've made some progress in our

hunt for America's earliest man. He must have come from the Old World because there's no sign of his having developed over here. And he must have come across Bering Strait because he couldn't reasonably have got here any other way. Now, to find our earliest man we must face a very troublesome problem—the question of time. Man has been measuring and recording the passage of time for about six thousand years. We'll have to get back farther than that, so we'll adopt one of nature's measurements as worked out by geologists. It's a tremendous climatic cycle known as the Ice Age. You've probably read that there are coal deposits within the Arctic Circle, which means that the arctic regions once had a climate warm enough to grow the plants that make the coal. At the other extreme of climate are the glacial deposits which prove that our Great Lakes region once lay under an ice sheet several miles thick in spots. Four times a great climatic change caused the formation of ice sheets over northern Europe and North America alike. They're ancestral forms, too; their descendants still live in the remote north, and Greenland is still covered. Three times in between these cold spells were warm spells, when plant and animal life changed completely, for the Ice Age was several hundred thousand years long.

There's our time cycle: four cold periods and three warm ones. It's important to human history because the oldest known remains of man in the Old World are found in earth layers or geologic deposits of the early Ice Age. And we can date the later remains by their position in the deposits of the succeeding periods. In short, the Ice Age is the great calendar of human history. Without it we could never hope to date America's earliest man.

By the time the last of the four great ice waves had started melting away, the human race was surprisingly well advanced. Instead of looking like hairy apes, its members had grown to resemble the men and women of to-day. They were using their brains and their hands to good purpose, making useful tools of bone, wood and imperishable stone. The changing forms of these tools give us a little calendar within the greater one of the climatic cycle, for they were being changed and improved constantly. In terms of our little calendar, the American Indian lives in the New Stone Age. That is, he knows how to make polished or smooth stone tools, as well as the earlier chipped or flaked tools. The New Stone Age began in Europe some ten thousand years ago, which suggests that the first Indians reached America some time during that period, after the last great glaciers had died away. If they had come much earlier, the argument runs, we should find their remains submerged in the glacial deposits of the last ice wave, or buried with the extinct animals of that period. With these remains should be stone tools of Old Stone Age type. All of which is good sound reasoning, because that's just the way it worked out in the Old World, in hundreds of instances.

In the past few years this view has been challenged by a whole series of discoveries. A human skull, not of the most modern type, was found under ten feet of glacial silt in Minnesota, near the southern edge of the last glacial wave. At several places in the Great Plains region, flint implements were found among bones of a species of buffalo that lived during the Ice Age. One of these finds was of eighteen such implements and thirty to forty bison, all of which lay buried under thirteen feet of a peculiar kind of soil called loess, which was blowing around the country when the glaciers were not so far away. In other instances similar implements lay among bones of the mammoth, an elephant now extinct. In Nevada a camp fire was found in an ancient dry cave below a solid layer of the dung of another extinct animal that

flourished in the late Ice Age, the ground sloth Nothrotherium. A cave in New Mexico yielded a flint implement with the bones of a musk ox, an animal built for a much colder climate than that of New Mexico to-day.

The implements in these finds were much like a type popular in Europe in very early New Stone Age times, perhaps ten thousand years ago. But recently, in the southern California desert, archeologists have found hundreds of camping places, with thousands of stone implements, most of which bear a strong resemblance to the European types of the late Old Stone Age, say 15 thousand years ago. These camps line the banks of three streams that no longer exist, their dry channels choked with drift sand. In one instance they cover the terrace or former beach line of a lake now dry, and this terrace stands forty feet above the present dusty bed. Native American camels and horses lived along these streams. We find their fossil bones strewn around the camps in thousands of fragments. When was the bleak California desert such a well-watered spot? Apparently not since the glaciers melted, the geologist answers, and by their melting created a humid climate.

So we have a growing body of new evidence to foster the search for America's earliest man. Apparently he saw something of the last great glaciers and the extinct animals that lived along their southern borders. The many dry lakes of the great inland basin, from Oregon to Arizona, were truly lakes to him. To clinch the argument, he hunted the same general group of late Ice Age animals, with the same general type of weapon, that were found in the Old World when the modern phase of the great climatic cycle was still young. And when was that? Here's our best answer to date.

A glacier melts fast in summer, slowly or not at all in winter. Every year it lays down a broad sheet of muddy water in one of the lakes that fringe its base. The mud settles in a thin film, and next year the process is repeated. These mud layers are visible to-day in many parts of Europe and America. Counting them, year by year, geologists have calculated that the last glaciers started their melting something like 20 thousand years ago. So we can estimate the age of America's earliest man as somewhere near that figure.

I must confess that this conclusion is not entirely satisfactory. It doesn't explain why nearly all our finds of early man in America are in the region south of the glaciated areas, which suggests that Canada and northern United States were still under the ice. But in that event, wouldn't Siberia and Alaska have been ice-bound, preventing migration? Well, not necessarily. Warm ocean currents may have freed the coastal belt of its ice mantle long before the interior was cleared. That's precisely what the Gulf Stream and the Japan Current are doing for northern latitudes to-day. Generally speaking, the sea is warmer than the land, and this would be the logical place for the glaciers to start their melting.

That's conjecture; in fact, much of what I've said and of what others say on this subject is conjecture. But here are a few facts as plain as the nose on your face. Man was in America when most of the big game animals were of the Ice Age group, not of the modern group we know to-day. He was here when the climate was far cooler and more humid than it is to-day. He made weapons that resemble most closely the types of the late Old Stone Age and the early New Stone Age in Europe. He apparently avoided the whole glaciated area of North America, for his remains are never found well within it.

Now the most conservative conclusion we can possibly draw from these facts is this. Man was in America at a time when its climatic and biotic conditions were still under the spell of the last great surge of the ice wave. Whether he came

during the long twilight of the Ice Age or earlier is an open question. Certainly he could not have come much later.

In other words, we've accumulated enough evidence to give us a fairly clear minimum age for man in America. But don't let anybody tell you we've necessarily reached as far back as the maximum. Most of our knowledge of man in the Old World comes from one country, France. France is smaller than the single state of Texas. If ever a tail wagged a dog, here's an instance. Centuries must pass before we'll know America as thoroughly as we know France. And what we learn may change the picture completely. We've taken just a few short steps on a long and difficult trail.

LIGHTNING

By Professor B. F. J. SCHONLAND

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I AM to speak to-day about some of our recent knowledge concerning the nature of the largest and most powerful electrical machines which exist on our earth —the natural machines we call thunder-storms. That the thunder-storm is an electrical machine was guessed three hundred years ago by the first workers on electricity. It was, however, that great American, Benjamin Franklin, who first showed in 1752 by direct experiment that thunder-clouds are electrically charged.

In spite of the great growth of electrical science and the frequent occurrence of thunder-storms, little more was learned about the workings of these natural electrical machines until comparatively recently. Within the last fifteen years, however, investigators in different parts of the world have succeeded in building upon Franklin's discovery a whole superstructure of accurate knowledge. They have measured the quantity of electricity generated by the cloud, the rate at which it is generated, the electrical pressure or voltage produced, and from these measurements it has proved possible to draw a number of very interesting and far-reaching conclusions.

Let me begin by describing some of these measurements and their results. First of all, the quantity of electricity stored up in the average thunder-cloud. This we find to be surprisingly small. Its value is about twenty coulombs of electricity, which at ordinary lighting pressure we could buy for 1/200 of a cent. It is the same quantity as flows through an ordinary lamp bulb in rather less than a minute. The thunder-cloud can generate this small quantity in five seconds. It holds it for a while, increasing it slightly against leakage and other losses incident to such a machine, and then is forced to let it disappear in the form of a lightning flash. Immediately after the flash it regenerates the electrical charge once more. This small quantity of electricity is, however, stored at a pressure of between one and five billion volts, about 100 times greater than the pressure developed in the biggest electrical set-ups yet devised by man. It is the enormous pressure which makes the discharge of such a small quantity of electricity so spectacular, so important and so dangerous.

While the visible effects of a thunder-storm, the flashes themselves, take place in a very short time, it must be remembered that the thunder-cloud machine is continuously generating electricity at this high pressure in the intervals between the flashes. Measurements show that the electrical energy continuously generated by a single cloud is about

three million kilowatts, three times greater than that obtained from the Niagara Falls and sufficient to supply a modern city of ten million inhabitants with light and power for the whole hour or so during which the storm is active.

The motive power behind this great electrical machine is the wind, which blows up from below the cloud with tremendous force, like a gale up a chimney. The power of the wind can be judged from the facts that this upward current of air supports the cloud with an average weight of about 300,000 tons of water, and on occasions can hold up hailstones of considerable size.

The number of thunder-storms occurring over the whole surface of the earth is very great. It amounts to sixteen million storms per year, or 44,000 every day. If you could take a quick glance around the globe at this particular moment of time, you would see approximately 2,000 thunder-storms busily at work. While this number may vary slightly from second to second, your count would be much the same at any moment at all in the course of the year. To get the total world electrical output from thunder-storms we must therefore multiply the figures given for a single thunder-storm by a factor of 2,000. This amounts to a total output of ten billion kilowatts continuously being generated by the world's thunder-storms, an amount which is rather greater than one ten thousandth part of the enormous energy which the sun gives to the earth in the form of light and heat.

The way in which thunder-storm energy is spent is of considerable interest, for the amount involved is so great that quite a small portion of it may produce an important effect. Tracing out the various activities of thunder-storms may carry one in this way into regions very far removed from the storm itself. I can, however, deal here with only one of these sidelines and that the most obvious. About half of the energy is spent in the form of lightning flashes, 100 of which occur in every second over the whole earth. The lightning flash is of course a gigantic electrical spark passing either from one part of the cloud to another or between the cloud and the ground. The flashes which I shall proceed to discuss with you are those taking place between the cloud and the ground.

The idea that a flash is a continuous spark, enduring for a second or more, is an optical illusion, for the lightning spark is really made up of a series of separate sparks which are called the separate strokes of the discharge. The number of strokes making up the whole flash may vary from one to ten or twenty, and the composite nature of the flash is responsible for the flicker which the eye sometimes observes. It is generally the first of the series of strokes which is the most intense and which carries the branches or forks. The branches are practically always directed downwards from the cloud, like the roots of a tree. Each stroke so far examined has been found to be itself a double discharge and to consist of two component strokes traveling in opposite directions.

Let me describe what the photographs taken in South Africa with special cameras tell us about the first and most important stroke of the series. If your eye were as quick as these cameras, you would first of all see a little tongue of light stretch down about fifty yards from the cloud in the direction of the ground. The light pauses, fades out for one ten-thousandth part of a second. Then the tongue reappears and stretches for another fifty yards. Another fade-out, another stretch, and so on. The process continues till the tongue of light reaches the ground. As it moves downward the tongue may sometimes form branches so that while one tongue proceeds to the ground other branching tongues travel outwards and downwards into the air. We call the tongue the "leader" to the stroke.

The instant the leader touches the ground the second or main part of the stroke begins. A brilliant flame sweeps upward from the ground towards the cloud, retracing the path blazed by the leader. As it sweeps upward it also spreads outward along the branches if any of these have been blazed by the leader. The first leader, on account of its pauses, takes a comparatively long time to reach the ground, about a hundredth of a second in many cases. The main stroke is much faster and traverses the same distance in about fifty millionths of a second. In the case of the second and succeeding strokes of the flash the procedure is slightly different. The leaders now exhibit no pauses but proceed steadily to the ground along the same track as the leader of the first stroke of the series. The main flame-like stroke leaps up in the same way as the first main stroke but with less development of light and heat.

As far as the majority of lightning strokes to ground are concerned, then, it appears that the first effect is the downward blazing of a trail from cloud to ground. The second is the much more rapid and intense illumination of this trail by a flame-like spark traveling back along the same path. The process may repeat itself in the same general way after short intervals, until the supply of electrical energy is exhausted and completely converted into the light and heat of lightning and the sound waves, developed as a result of this sudden heating, which we call thunder.

The full explanation of these events is involved and more information must be obtained before we can feel that the mechanism responsible for them is fully understood. It is hoped, however, that when this new information is combined with the experiments on artificial lightning made in the great research laboratories of the United States and elsewhere we may at last be in a position to understand completely the manner in which these gigantic electric sparks are initiated.

Such an understanding should be of aid in the development of still better methods of protecting life and property against the effects of lightning. It should also enable us to apply the knowledge gained from sparks several miles long to the smaller ones which are of such importance to our every-day life. Even if we can not do much to tame the lightning we may learn from it how to design better sparkplugs for our automobiles.

THE COOLING OF THE EARTH AS A PROBLEM IN METALLURGY

By Dr H. E. STAUSS

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THEORIES of the origin and character of the earth are numerous, but most agree in assuming, in analogy with the present condition of the sun, that the earth was once molten, and that it has cooled, at least on the surface, to produce the earth as we know it to-day. What the interior of the earth may be, liquid or solid, no one knows We may be living on the crust of a ball of fire, or we may be living on the surface of a solid sphere The data of seismology are interpreted to mean that the earth consists of several concentric shells The only clues to the character of these shells are their elastic constants, as deduced from the propagation of earthquake waves, and the average density of the earth The interpretation of the clues is complicated by the unknown effects of temperature and pressure inside the earth The average density is about two thirds that of nickel. The concentric shells of the seismologists are thought to be a center core of liquid, with about half the radius of the earth, a shell of the rock dunite forming most of the rest of the earth, and then a thin superficial layer of granite lying under the outermost strata known to geologists.

Since the earth is a cooling body, its behavior during cooling and solidification is of extreme interest to science, but unfortunately that behavior is as yet little more than a matter of speculation. In view of the fact that up to the present the science of metallurgy has given more study to the cooling and solidification of molten liquids than have other sciences, it is interesting to apply the results of metallurgy to the cooling of the earth, without trying to correlate them closely with other theories and without attempting to determine whether the phenomena to be expected have already occurred or are still to happen. The application will suffer, as do all other speculations regarding the interior of the earth, from ignorance of the effects of combined high pressures and high temperatures These effects will be ignored, as will such refinements as radioactivity and the transmutation of matter and energy.

There are about ninety known terrestrial elements, most of them metals or metalloids Any metallurgist confronted with the problem of studying the equilibrium conditions of the ninety-odd elements would be driven to despair Binary systems of metals are his usual task, occasionally he tackles the complexity of ternary systems. Quaternary systems are not studied in detail. Yet nature has mixed the ninety-odd elements, and any adequate study of what she has done must follow her. At present what she may have done can only be considered sketchily in the light of the behavior of the simpler systems.

Probably the best starting-point for the metallurgical study is the earth condensed to liquid, hot enough still to have a metallic atmosphere. As the earth cooled further, condensation proceeded, and at the same time profound internal changes were likely to occur. It is well known that not all liquids are mutually miscible in all proportions, oil and water being the best-known examples. Liquid metals are no exception to the rule. For example, liquid zinc and liquid lead,

which are miscible at elevated temperatures, separate at lower temperatures and go their independent ways until they freeze into two distinct metals The mixture of 50 per cent. zinc and 50 per cent lead, by weight, for instance, is a single liquid above 900° C (1650° F.), but when it has cooled to 900° C., it separates into two layers, although freezing does not begin to occur until 419° C. (786° F). If the starting-point of this discussion has been taken sufficiently far back, the temperature of the earth was high enough to maintain all the elements in one homogeneous liquid, except as gravity may have affected the distribution of density. But as the earth cooled, it may well have separated into two or more liquids. If such a change did occur, it had a profound influence on the earth. The heavier liquids fell towards the center, the lighter ones rose towards the surface. The redistribution of mass changed the radius of gyration of the earth, and hence its rate of rotation and its day, shortening the latter. The changes presumably would be slow, but they conceivably might be cataclysmically swift. Even after the earth had cooled far enough to have a crust and to support life, such internal rearrangements could occur, with tremendous effect upon the surface and the organisms on the surface; and the changes may have occurred not once, but several times. Such possibilities indicate the complexity of the problem of the reconstruction of the earth's past.

While the earth was cooling and while it was still entirely liquid, chemical reactions began to occur, those which resulted in the formation of compounds, stable at high temperatures, either as solids or as liquids. These compounds separated from the matrix, and the lighter ones floated to the surface to form the crust. Dissolved oxygen reacted to form many of the refractory oxides—aluminum oxide, silicon dioxide, beryllium oxide, magnesium oxide, ferric oxide At the appropriate temperatures some of these compounds reacted among themselves. Many oxides, for example, combined with silicon dioxide to form low-fusing silicates that rose to the surface as liquids Phosphorus might ultimately have floated to the surface in liquid phosphates. Such reactions at high temperatures in molten metals are in common use in the melting-room to remove traces of undesirable elements, and there can be little doubt that they would occur during the cooling of the earth. In fact, the earth's crust is almost entirely such products. Silicates are wide-spread. Aluminum and iron are the most common metals. Many of the primitive rocks are glasses —silicates in composition. Our very outermost crust is the result of the physical and chemical reactions that have since occurred to these primitive rocks.

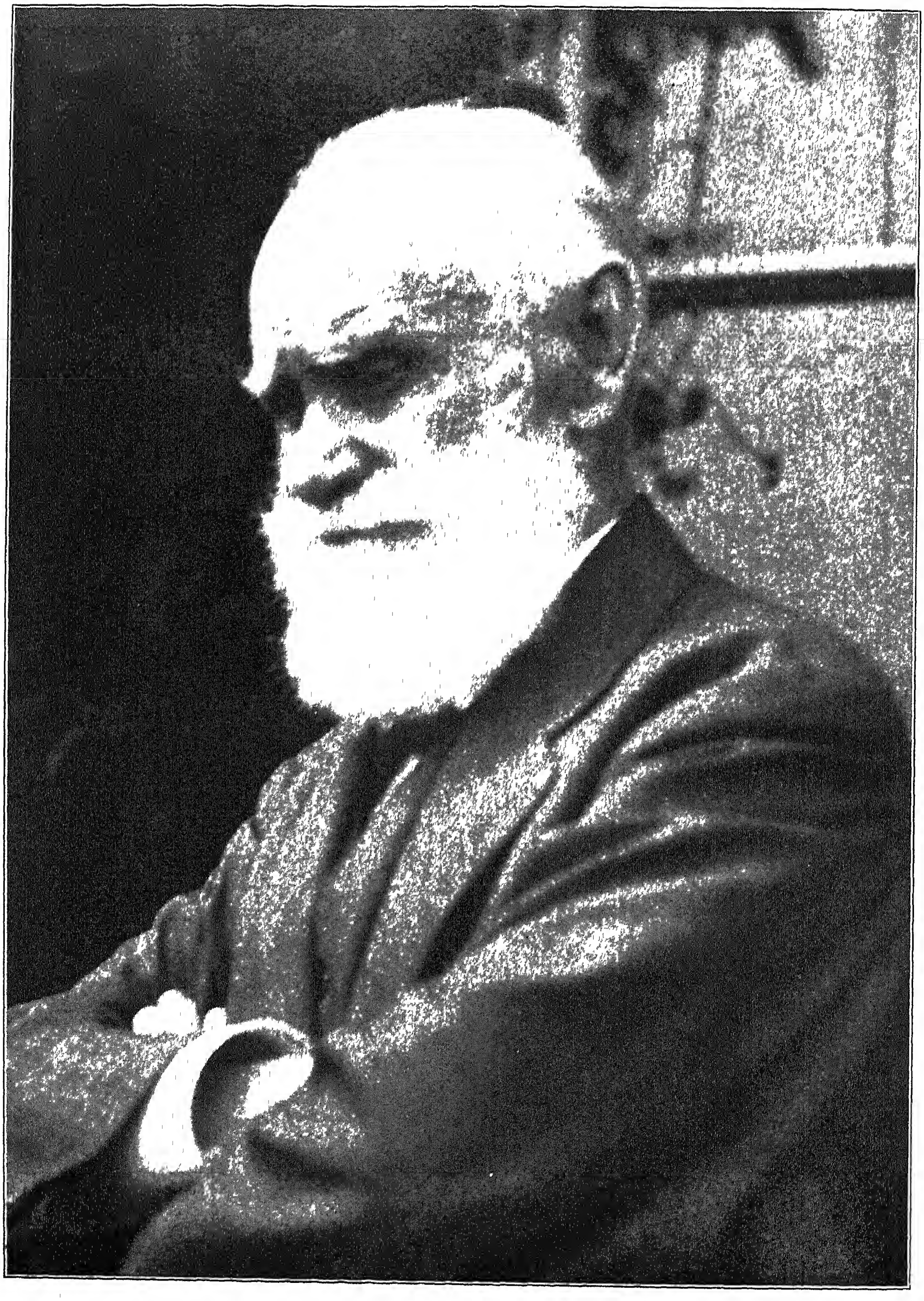
While the earth was yet a molten ball, it no doubt contained in solution some of the gaseous elements. In most cases, the ability of a molten metal to dissolve gases increases as the temperature rises; or, in other words, as the temperature of a molten metal falls, the solubility of gases decreases and the gases begin to be liberated. At the freezing-point the decrease in solubility is discontinuous, and practically all the dissolved gas is rejected. The earth's atmosphere can be explained as being composed of the gases once dissolved in the molten earth and rejected by its parts upon their cooling and freezing Nitrogen, being relatively inert, has escaped to form most of the earth's atmosphere. Oxygen and the other chemically active gases have been mostly trapped in chemical compounds —hydrogen and oxygen together, in direct chemical reaction, in water, oxygen in many oxides, chlorine in sodium chloride.

When the temperature of the earth

had cooled sufficiently, crystals began to precipitate, both in the liquid metal and in the liquid compounds which had not solidified as glasses. Where in the earth's mass precipitation occurred depended upon both the temperature and the composition of each layer. Heavy, high-melting constituents at the center might freeze out before lighter, lower-melting ones nearer the surface, if the temperature gradient in the interior was not too steep If the gradient was great, solidification would begin near the surface. In general, the solid crystals were more dense than the liquid matrix and sank as they formed until they encountered their own densities Here, however, they might encounter higher temperatures again, and begin to melt. Any such occurrences, of course, led to great migrations of material in the earth's interior, disturbing its rotation, and also led towards a flattening of the temperature gradient in the earth's interior. When conditions had come to such a pass that at any position crystallization could proceed without interruptions by melting, it is unlikely that uniform concentric shells were formed. A slowly cooling alloy, such as we are assuming all or part of the earth to be, crystallizes in branching dendrites, in structure appearing like the well-known forms of snowflakes. The earlier freezing portions form the dendrites, the later freezing parts fill the interstices as liquid, and finally freeze in them. For a period of time freezing is primarily along the dendrites. Thus it is very possible that at one time the interior of the earth was like a ball of liquid, reinforced with great ribs of crystals

While freezing occurred, great quantities of heat were released. If this heat was not liberated uniformly over the period during which it was available, the history of life on the outer crust must have fluctuated with the changes in the rate of release of energy. The crust acts as a great insulating blanket on the interior of the earth, but its temperature would vary somewhat to permit the dissipation into space of varying quantities of heat. By its blanketing action it would force the temperature beneath it to rise when heat was liberated; and this rise would melt the base of the crust, thinning the latter, and thus, by reducing the thickness of the insulation, raising the temperature of the outer surface. Climatic fluctuations, such as the great ice ages, may well have resulted from the manner of the cooling of the earth.

The behavior of the gases dissolved in the molten interior deserves somewhat more attention than it has received so far. When gas is rejected in a molten liquid, it rises to the top and escapes if possible. When the exterior of the metal is already frozen solid, it collects as a bubble in the yet molten part. In the melting-room many a bar is found to contain these bubbles or "gas holes." Once the surface of the earth was solidified, rejected gases could no longer escape harmlessly to the surface The part that could drifted upward to find lodging under the solid crust, possibly to leak out slowly through minor fractures in the crust, conceivably to push up the bulges that we call continents. However, when too much gas was liberated, the bubbles might be subject to extreme pressures, and might eventually break through the crust at a weak spot, as a volcano, for example. The gases to be expected from metallurgy are predominately oxygen and hydrogen, but these two react readily to release steam from the melt, and oxygen will react with dissolved carbon to release carbon monoxide or dioxide. In actual fact volcanoes release vast quantities of steam. It is possible that they are exterior openings of the vents connecting the earth's surface with the still solidifying interior.



IVAN PETROVITCH PAVLOV

THE PROGRESS OF SCIENCE

IVAN PETROVITCH PAVLOV

On the 19th of February, 1916, the *Lancet, British Medical Journal* and *Journal of the American Medical Association* all carried detailed obituaries of Ivan Petrovitch Pavlov, confusion having arisen over the death of E V Pavlov, the surgeon. All three notices had been prepared by distinguished physiologists, and it is significant that Pavlov's work on gastric physiology was described by each one; but the notice in the *Lancet* makes no reference at all to conditioned reflexes, and in the other two notices they are mentioned briefly and in the vaguest terms Pavlov's epoch-making studies on the activities of the cerebral cortex, begun about 1902, were practically unknown outside of Russia until Gleb van Anrep brought tidings of the new work to England just before the war; Pavlov himself had actually made a preliminary announcement in London in 1906 and again at Gröningen in 1913, but not until Bayliss' "General Physiology" was published in 1917 were conditioned reflexes generally understood. The English-speaking world waited, moreover, until 1927–28 for the Anrep and the Gantt translations of Pavlov's lectures, which for the first time gave adequate information concerning Pavlov's views and the experimental data upon which they were based.

Pavlov's death, which was authoritatively announced from Moscow on February 27, 1936, brings with it a sense of deep personal loss to physiologists the world over, and especially to those who had the good fortune to attend the Fifteenth International Congress in Russia last August There one saw in his own surroundings the man who had already become a legendary figure. One visited the three laboratories which he personally directed, one witnessed his apotheosis by a proud and generous people—a form of recognition more sumptuous and elaborate than had ever before been accorded by a government to a scientific man. Pavlov had been recently ill, but the Fates seemed to have decreed that he should live until the Physiological Congress was over Only a week before the great gathering at Leningrad, Pavlov and one of his sons made a surprise trip to London to attend the second International Neurological Congress, and he was able to return to Leningrad only a few days before his own congress commenced. Both in London and in Leningrad he was unbelievably active, reading addresses and papers himself, attending the scientific sessions, being host to delegates, entertaining at luncheons and dinners, and finally presiding at that memorable feast at Detskoye Selo, the official dinner of the Physiological Congress held in the ancient banqueting halls of the Catherine Palace; it was attended by some 1,600 delegates. When Pavlov appeared on that memorable occasion he received a stirring ovation which continued, almost without interruption, until the next day.

Ivan Petrovitch Pavlov, the first son of a village priest, Peter Dimitrievitch Pavlov, of the district of Rjäzan in Russia, was born on September 14, 1849. He received his early education from a local school and, later, intending to take holy orders, he entered a neighboring theological seminary. At the age of sixteen there fell into his hands a copy of the new Russian translation of "The Physiology of Common Life," by George Henry Lewes, that versatile character who played so large a part in the life of George Eliot. Lewes's book contains several remarkable chapters entitled, "Feeling and Thinking," "The Mind

and the Brain," "Our Senses and Sensations," and "Sleep and Dreams"; these chapters form a highly important landmark in the history of physiological psychology, not only because they stimulated the young Pavlov (and incidentally also William James), but because they represent one of the earliest objective treatises on the functions of the cerebral hemispheres. Under the stimulus of this book, a copy of which he kept always beside him as a *comes viae vitaeque*, Pavlov left theology and determined to follow biological science as his career. It is thus interesting to realize that the crucial stimulus of Pavlov's life career came from England.

Other details of Pavlov's life are well known, thanks to the excellent biographical sketch published in 1929 by Gantt in his translation of Pavlov's lectures He entered the University of St. Petersburg in 1870; in 1878 he was first heard from outside of Russia through a series of papers on the conditions affecting the blood pressure (unanesthetized dogs). In 1879 there followed three papers on the pancreas, one describing his method —similar to that of de Graaf—for making a pancreatic fistula. Not until 1889, however, did one of Pavlov's pupils describe (*Centralbl. f Physiol.*, 3: 113–114, 1889) the new method for studying uncontaminated gastric juice. Fistulous openings were made in the stomach and after a prolonged period of careful nursing care, by Madame Pavlov (Serafima Karchevokaya, whom he married in 1880 and who survives him) and his four children, the animal was restored to health. Then followed a series of experiments on sham feeding and analysis of psychic secretion, which culminated in 1904 in his receiving the Nobel prize.

That Pavlov should after 1902 have turned his attention to the nervous system was logical in view of the direction which his work on digestion had taken. To use his own words (Gantt ed., p. 37): "For many years previously I had been working on the digestive glands. I had studied carefully and in detail all the conditions of their activity. Naturally I could not leave them without considering the so-called psychical stimulation of the salivary glands, *i.e*, the flow of saliva in the hungry animal or person at the sight of food or during talk about it or even at the thought of it. Furthermore, I myself had demonstrated a psychical excitation of the gastric glands." The conditioned reflex was the direct outcome of these studies, but it is sometimes not appreciated that E L Thorndike, Franz and Yerkes in this country undertook studies of a similar character at about this time, and Pavlov in more than one place has referred to their priority. Thus Pavlov states (*ibid.*, p. 40). "Some years after the beginning of the work with our new method I learned that somewhat similar experiments on animals had been performed in America, and indeed not by physiologists but by psychologists. Thereupon, I studied in more detail the American publications, and now I must acknowledge that the honour of having made the first steps along this path belongs to E. L Thorndike. By two or three years his experiments preceded ours and his book, "Animal Intelligence—an Experimental Study of the Association Processes in Animals," 1898, must be considered as a classic, both for its bold outlook on an immense task and for the accuracy of its results."

In a sense Pavlov was an unsophisticated child of nature. Naive, direct, untouched by convention or prejudice, he set out to describe the things he saw in the boldest terms. In addition he had the genius to devise a new form of experiment which was adequate for analysis of a problem which no one, save Thorndike, had yet approached. His philosophy had little profundity, and yet by its very simplicity and directness it has caused men to think in new terms. Pavlov was guilty of over-simplifying an

extraordinarily complex subject, but as a first approximation in a field where doubt, mystery and prejudice reigned before, it had the outstanding virtues of a new and compelling hypothesis: it crystallized a great problem and clearly indicated the path to be followed for its solution.

Sherrington's prophetic remarks made in 1905 have fresh significance to-day ("Integrative Action of the Nervous System," p. 307): "New methods of promise seem to me those lately followed by Franz, Thorndike, Yerkes and others; for instance, the influence of experimental lesions of the cortex on skilled actions recently and individually, *i.e*, experientially, acquired Despite a protest ably voiced by v. Uexkull, comparative psychology seems not only a possible experimental science but an existent one. By combining methods of comparative psychology (*e g.*, the labyrinth test) with the methods of experimental physiology, investigation may be expected ere long to furnish new data of importance toward the knowledge of movement as an outcome of the working of the brain." At the time these words were uttered, Pavlov had also begun to vindicate them in a brilliant manner, and he lived to carry the work further than any other investigator in the field.

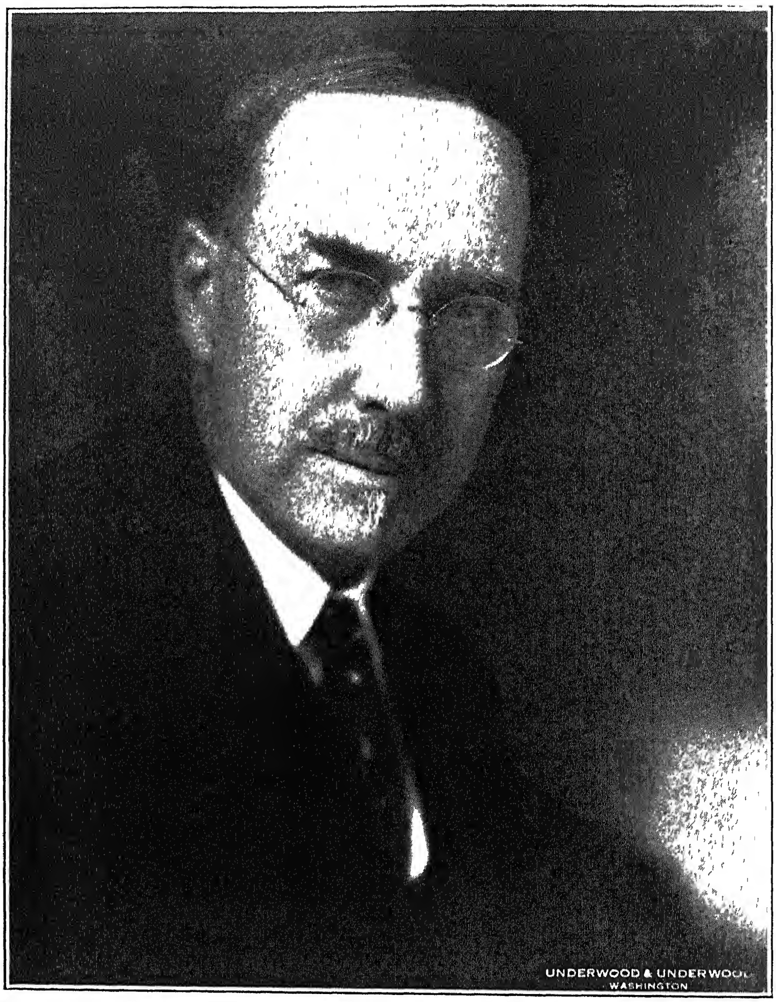
J. F. F.

DR. MERRIAM'S CONTRIBUTIONS TO THE DEVELOPMENT OF VERTEBRATE PALEONTOLOGY ON THE PACIFIC COAST[1]

DR. MERRIAM is both author and interpreter of an epic poem of unsurpassed grandeur This poem is not written in verse but in the sober language of science It is the epic of the history of vertebrate life on the Pacific Coast, and the story is told in a long series of publications, chiefly in the bulletins of the Department of Geology of the University of California, but of late years also in the paleontological memoirs and papers of the Carnegie Institution of Washington, D. C. More than sixty localities scattered over California and the adjoining states have yielded the historical documents, in the shape of fossilized animal and plant remains, upon which this great epic has been built up The brief moments at our disposal this evening permit us to glance at only a few of the scenes of this gigantic drama, which is still winding its slow way along after some four hundred and fifty million years of continuous performance.

Let us pass over the earlier chapters, which are indeed not nearly so well represented on the Pacific coast as they are in the East, and let us stop for a moment in the middle Triassic Period, about one hundred and sixty million years ago. The records of this period are preserved in the limestones of what is now the West Humboldt Range in Nevada. At that time the broad sea covered the place where now the Rockies rear their peaks, and in the long swell of a sunny Pacific day strange creatures disport themselves. Some of them are veritable sea serpents about thirty feet long They look at first like long-snouted but slender dolphins Dr Merriam, our paleontological Dante, tells us, however, that they are called ichthyosaurs, or fish-lizards, but that in truth they are neither fish nor lizards nor any combination of the two; but that they are descendants of land-living reptiles of still earlier ages, reptiles which had been tempted into the sea by the abundance of food and had gradually changed their legs into paddles, their tails into rudders But if you wish to learn more about the origin, rise and decline of this race of sea monsters, I refer you to Dr. Merriam's monograph on "Triassic Ichthyosauria" in the Memoirs of the University of California,

[1] Address upon presentation of Dr. John C. Merriam for the Gold Medal of the American Institute, February 6, 1936.



DR JOHN C. MERRIAM
PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

Volume I, 1908 This work in my opinion should be one of the major documents of all students of evolution.

After the disappearance of the Triassic ichthyosaurs scores of millions of years pass by, the ponderous dinosaurs appear, live their brief day and trample each other to death in the last waterholes, as the Rocky Mountains rise above sea level and the low swampy coast lands are gradually raised into mountains and grassy plains

New actors then come on the stage, the varied placental mammals of the Upper Eocene times, some forty-odd millions of years ago, and their successors of the Lower Oligocene a few million years later. As yet the fossil records of these horizons, which have been recently discovered in localities near Death Valley, California, are rather scanty, but as described by Dr. Chester Stock they are of great importance because they serve to tie in the lower levels of the California mammalian sequence with certain faunas of corresponding age found in the Rocky Mountain basins of Wyoming and on the ancient plains of Colorado, Nebraska and South Dakota And just as the archeologists endeavor to date their newer dis-

coveries in Asia Minor by comparison with the sequence of cultures already well known in Egypt, so are the paleontologists under Dr Merriam's leadership slowly correlating the torn earlier chapters of the mammalian life record of the Great Basin of California with better known records of the Rocky Mountain and Great Plains regions of the East

More millions of years roll on and we come to the far more abundant records entombed in the great formations of the John Day Basin in Oregon, of Upper Oligocene age, followed by the Mascall of Miocene age and the Rattlesnake of Pliocene times Far to the south, in what is now the Mohave Desert, the story is carried into later chapters of the Upper Miocene and Pliocene by thousands of fragments, which Dr. Merriam and his collaborators are still diligently studying and describing During these long ages the ordinary business of living and breeding, of feeding, fighting and dying, was eagerly carried on by countless herds of animals, especially the three-toed horses, antelopes with bizarre and twisted horns, rhinoceroses, mastodonts, primitive elephants and others with strange names Nor were their pursuers, the dogs and bear-dogs of assorted sizes and shapes, the saber-toothed cats, the jaguar-like cats and many other carnivores, in their attacks upon the frightened herbivores any less stealthy or persistent or ferocious than are their modern relatives.

At intervals the face of nature would be convulsed and volcanoes would pour out vast suffocation and destruction upon the plant and animal worlds But ever and again after things had quieted down, new settlers would come in and the slow preparations for the next holocaust would be resumed.

At last the Ice Age settled slowly down upon Europe and even the eastern United States, but California, true to its traditions, maintained its famous climate and was the refuge of species that could not endure the rigors of the East. Near Los Angeles beneficent nature, evidently with Dr. Merriam in mind, arranged a most ingenious series of traps in the form of pits filled with asphalt, in which she patiently collected thousands of parts of saber-toothed tigers and dire wolves trapped with their victims, the giant ground sloths This section of the epic is set forth in the monograph on "The Felidae of Rancho La Brea" by John C Merriam and Chester Stock

Near the end of the Pleistocene chapter of the epic great caverns were formed in the ancient marine limestones, and into these caverns crept a strange assortment of woolly beasts, perhaps related to the musk-ox, which have been celebrated by Dr. Merriam, Dr. Sinclair and Mr. Furlong.

But during all the later ages while Dr. Merriam watched and sang the drama of vertebrate evolution, he was steadily searching for traces of nature's greatest devastator, *Homo sapiens*. At last some of his sleuths have discovered near Folsom, New Mexico, and in other localities, an abundance of peculiar flint points, with other evidence that these early Americans of perhaps some twelve thousand years ago were busily engaged in the congenial task of exterminating a contemporary species of American bison

Perhaps it was the vision of eternal creation, carnage and destruction, the mystery of the emergence of new forms, and the inner beauty that he sees through fossil bones, which have reacted to make Dr. Merriam one of the world's greatest conservationists To him, and to his friend, Madison Grant, future generations of Americans will owe the arrest of the depredations of their species upon the noble sequoias.

Now I have unfortunately left myself but a moment to speak of all the mighty residue of Dr. Merriam's activities But what can one do in the case of a man who has literally made the universe his laboratory? How could I tell adequately

of the work of the great astronomic observatory at Mount Wilson, of the magnetic survey of the world in the good ship *Carnegie*, of the oceanographic laboratories at Woods Hole and Bermuda, of the Station for Experimental Evolution at Cold Spring Harbor, of the Carnegie Institution Laboratory for the Study of Embryology in Baltimore, or of many other important research projects which have been maintained by the Carnegie Institution of Washington under the presidency of Dr. Merriam? Or how could I summarize in a few minutes his highly constructive discussions of the rôle of science in human affairs?

Let it be enough to say that his colleagues and fellow citizens everywhere appreciate his far-sighted and judicious labors in their behalf. They recognize their great debt of gratitude to him and hold him in the highest honor and affection.

WILLIAM KING GREGORY

OPENING OF THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY AT THE ROCKEFELLER CENTER

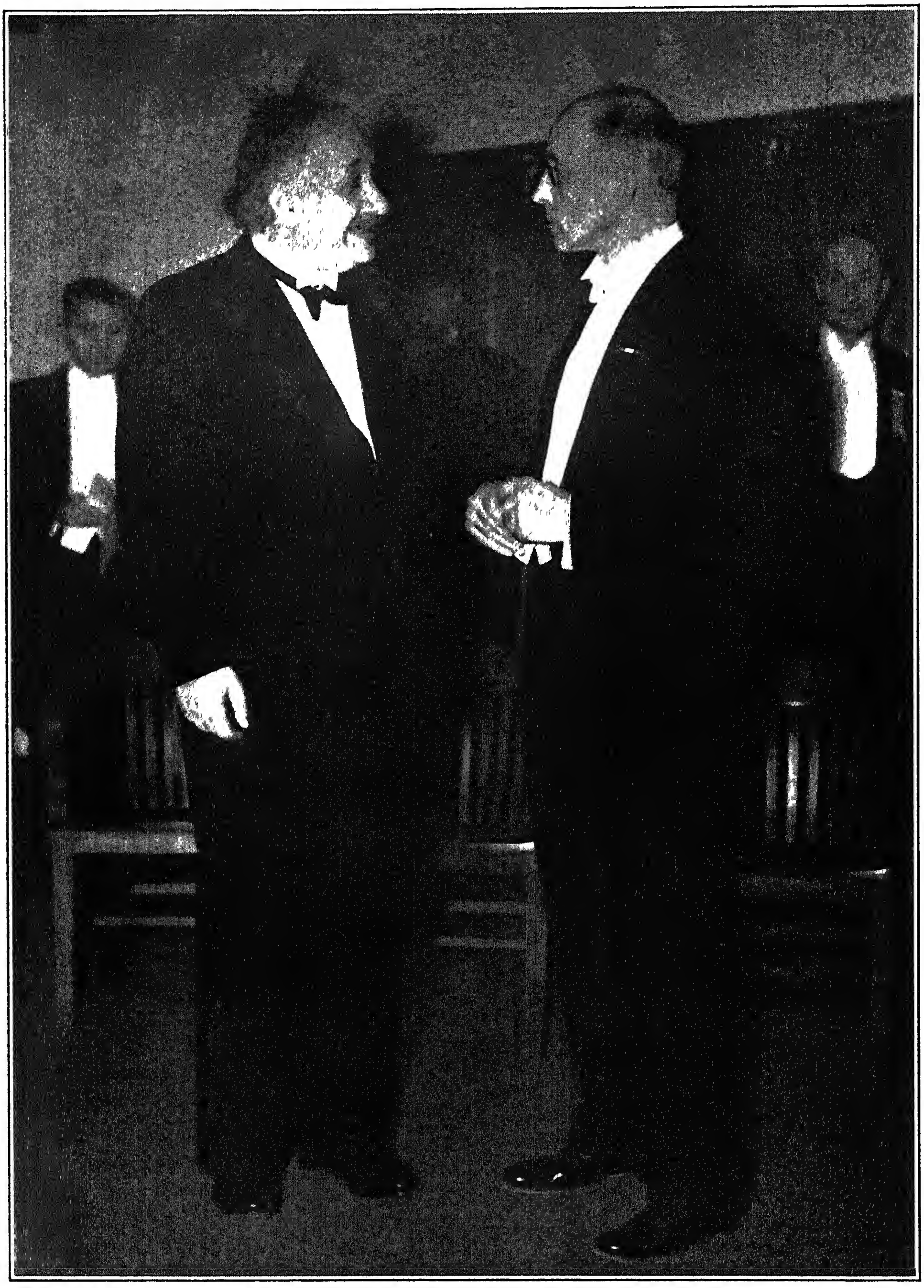
HERALDED with a spectacular scientific demonstration, which spanned the Atlantic Ocean and reached across the continent in the flash of a few seconds, and hailed by world-famous men of science as an event of epoch-making importance, the New York Museum of Science and Industry opened the doors of its permanent home in the RCA Building of Rockefeller Center on February 11.

Here, against a background of exhibits showing their evolutionary progress, are the newest developments of the scientific and industrial worlds, displayed in such fashion as to present before the observer's eyes a striking picture of the mechanics of everyday life in actual operation. Thus the visitor pushes buttons, pulls levers and turns cranks and sets in motion generally the wheels of the machinery underlying the mysteries of transportation, communication, electrotechnology and numerous other of the foundations on which the modern world is built.

For the Museum of Science and Industry is preeminently a place where things move and, even better, a place where people themselves make things move, thus staging their own demonstration. In practically every other kind of museum, the visitor's only part is to stand and look, to walk around and look again. In this unique museum, one of less than half a dozen such in the entire world, he puts on his own show and enjoys himself thoroughly in so doing.

Of the eleven permanent divisions of the museum—communications, aviation, highway transportation, marine transportation, railroad transportation, power, textiles, housing, machine tools, electro-technology and food—every one of them except the housing section includes innumerable moving exhibits, either in full size or in scale models. In the aviation division, for example, one of the main attractions is the so-called "pilot trainer"—the airplane cockpit into which any one may climb and, operating the dials on the instrument board in front of him, maneuver the machine of which he is temporarily in sole control, this way and that—in any direction except off the ground.

In the transportation section, the visitor can start the wheels of locomotives turning, operate railroad signals and flash important lights—all in miniature models from the early crude designs of locomotives to the stream-lined mogul of to-day. The communications section offers a practical demonstration of ship-to-shore radio communication by operating the apparatus, in miniature, by which a ship determines its position in relation to lighthouses sending out radio



PROFESSOR ALBERT EINSTEIN AND DR FRANK B JEWETT
AT THE OPENING EXERCISES IN THE ROCKEFELLER CENTER. DR JEWETT IS PRESIDENT OF THE BOARD OF TRUSTEES OF THE NEW YORK MUSEUM OF SCIENCE AND INDUSTRY

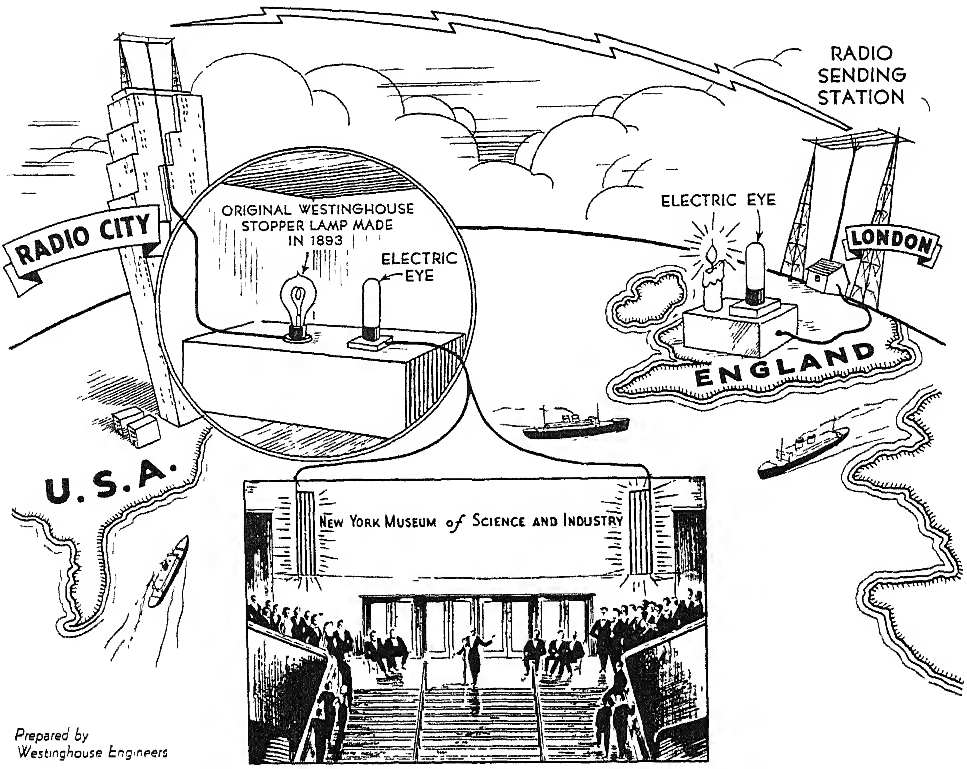
signals By pressing a button and turning a knob, one maneuvers the tiny radio receiving loop on the prow of a small vessel into the proper position to catch the signals from the lighthouse which flashes in the distance An exhibit which demonstrates each step of the dial telephone system, synchronized to each motion made as the investigator puts through a call on an actual dial telephone, is another favorite plaything with museum visitors

The electro-technology division, with its moving exhibits demonstrating magnetism, the generation of electric current, high frequency transmission, the principle of radio tuning and a host of other "miracles" in this highly technical field, draws crowds to watch the gadgets whirl around and illustrate for them the mysterious whys and wherefores of many things they take for granted in the ordinary routine of living. Modern machines used in various types of industrial plants—automobile factories, iron and steel works, power plants, refrigerating plants and the like—go through their paces for the daily visitors likewise.

In addition to the permanent exhibits, a series of special exhibits will be seen at the museum, arranged by outstanding research laboratories and industrial concerns as occasion arises to show something of unusual interest or some new development along scientific lines In this way, the museum will keep the public informed in up-to-the-minute fashion in regard to happenings in the fields it covers.

At the present time, the special exhibits are four in number, assembled by the laboratories of the Eastman Kodak Company, the General Electric Company, the Goodrich Rubber Company and the Bell Telephone Company The first of these offers the latest developments in photography, color photography, radiography, etc, with much of practical interest to the amateur photographer as well as the demonstration of scientific principles. In the second, a favorite attraction, among many others, is the new powerful magnetic alloy, capable of lifting sixty times its own weight. The Goodrich Company permits visitors to push a button and set in motion the de-icer, the device by which the wings of the modern airplane are kept free of ice when flying

SIR WILLIAM BRAGG AT THE DESK OF MICHAEL FARADAY
IN THE ROYAL INSTITUTION OF GREAT BRITAIN. AT THE RIGHT IS THE CANDLE WHICH TOOK PART IN LIGHTING THE MUSEUM ON THE OPENING NIGHT.



THE PATH TRAVELED BY THE ELECTRIC IMPULSE FROM LONDON

THE IMPULSE SET IN MOTION BY THE CANDLE FLAME, LIT BY A MATCH STRUCK BY SIR WILLIAM BRAGG, DIRECTOR OF THE ROYAL INSTITUTION OF GREAT BRITAIN, WAS PICKED UP BY A PHOTO-ELECTRIC CELL AND RELAYED ACROSS THE OCEAN, WHERE A SECOND PHOTOELECTRIC CELL RECEIVED IT AND CAUSED IT TO LIGHT THE 50-YEAR-OLD ORIGINAL INCANDESCENT LAMP THE LATTER TURNED ON THE HIGH INTENSITY LAMPS BORDERING THE ENTRANCE OF THE MUSEUM.

through low temperatures, while the Bell Telephone Laboratory has set up a mechanism which affords one the unique experience of listening to himself talk on the telephone.

All this is in line with the expressed purpose and wish of the founder of the museum—Henry R Towne, whose will brought into existence and endowed the institution in 1927. It was Mr. Towne's feeling, as set down in the will, that while "the United States is the greatest industrial nation of the world, with organized industries exceling those of all other countries in magnitude and efficiency, our national achievements in this great field are unrepresented by any permanent collection of examples illustrative of their history and growth. We do not possess any permanent exposition of American achievements in the peaceful arts, which great groups include the arts of agriculture and animal industry; of forestry and woodworking, of mining and metallurgy; of transportation and communication; of engineering and architecture, of industrial chemistry; of electrical mechanism; of aeronautics; of the metal, textile and building trades, and of the innumerable subdivisions of all these, including their products, processes and implements."

Other important groups interested in maintaining and constantly expanding

the scope of the museum so that it may most successfully carry out its program of presenting to the public a continuing and dramatic demonstration of important scientific developments as they take place are the Rockefeller Foundation, the New York Foundation and the Carnegie Corporation

The high point in the elaborate program which dedicated the new home of the museum was the lighting in the museum of a bank of forty new mercury lamps, the last development in artificial lighting, as the result of a candle flame lit in London. Seated at the desk of Michael Faraday, where Faraday worked out his epochal experiments in electromagnetism, Sir William Bragg, director of the Royal Institution of Great Britain, struck a match and lit a candle, the sound plainly audible on the radio to the audience of several thousand gathered in the museum. A photoelectric cell on the same desk picked up the rays and sent out an impulse over the Atlantic. In New York the impulse was filtered from Sir William's speaking voice and sent to another photoelectric cell in the museum. There it caused to glow for the first time in fifty years the original incandescent lamp manufactured by the Westinghouse Company and taken from the Westinghouse Museum for the occasion, and, in turn, the old lamp turned on the bank of mercury lamps.

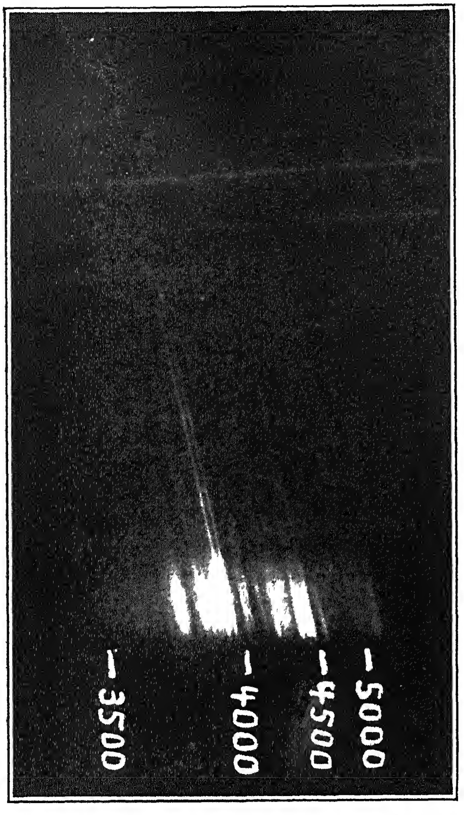
Professor Albert Einstein took part in the dedication program, other speakers being Dr. Robert A. Millikan, Nobel laureate in physics, Dr. Irving Langmuir, Nobel laureate in chemistry, Amelia Earhart, Mayor Fiorello La Guardia and Dr. Frank B Jewett, president of the Board of Trustees of the New York Museum of Science and Industry.

M. C. M.

PHOTOGRAPHY OF METEOR SPECTRA

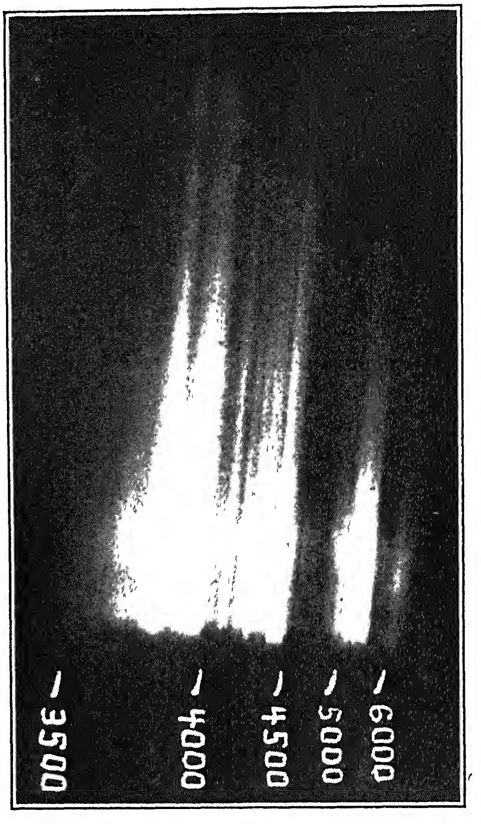
There is no branch of astronomical photography that has a greater appeal to the sporting instinct than the photography of meteor spectra This is because no one can predict when, or in what part of the sky, a bright meteor will appear, and when it does appear the whole phenomenon rarely lasts longer than two or three seconds. A program of meteor photography thus resolves itself into something very much like a fishing expedition, where the observer sets up a camera instead of throwing out a line and then leaves the shutter open, hoping that a bright meteor will cross that part of the sky towards which the camera is directed. The thrill of securing a particularly fine meteor spectrum is also closely akin to the elation experienced in landing a fish of record weight.

The best camera to use for this purpose is a small one having a lens with a focal length lying in the range between four and twelve inches and a speed ratio F 4.5. Nominally faster lenses have relatively poor definition in the outer part of the field and so are unsuitable. A prism with refracting angle between 25 and 35 degrees is mounted directly in front of the lens and as close to it as possible. This completes the meteor spectrograph and it only remains to set it up on a stationary mounting and make exposures on the sky which, on a dark moonless night, will average about an hour in length. As a result of recent observational programs it appears that on ordinary nights there is a chance of photographing one meteor spectrum in, roughly, 250 hours' total exposure time. If, however, observations are made during the nights of some of the well-known showers such as the Leonids or Perseids the probability is that a spectrum will be secured for every 10 to 15 hours of exposure time. Nothing better illus-



A METEOR SPECTRUM, TYPE Y

PHOTOGRAPHED ON DECEMBER 15, 1931, AT THE BLUE HILL OBSERVATORY, MASSACHUSETTS. THE METEOR APPEARED ABOUT AS BRIGHT AS JUPITER AND OF AN ORANGE COLOR, LEAVING A TRAIN VISIBLE FOR TEN SECONDS THE TWO PROMINENT LINES IN THE SPECTRUM ARE GIVEN BY IONIZED CALCIUM WAVE-LENGTHS IN ANGSTROMS ARE INDICATED.



A METEOR SPECTRUM, TYPE Z

PHOTOGRAPHED ON NOVEMBER 18, 1935, AT THE DUNLAP OBSERVATORY, RICHMOND HILL, ONTARIO. THIS METEOR WAS A BLUE LEONID ALMOST AS BRIGHT AS VENUS, LEAVING A TRAIN THAT REMAINED VISIBLE FOR SEVEN SECONDS. THE MAJORITY OF THE LINES IN THE SPECTRUM ARE GIVEN BY IRON. WAVE-LENGTHS IN ANGSTROMS ARE INDICATED

trates the part luck plays in meteor photography than the results of a recent program. This comprised 1,350 hours of photographic exposures and on the very last plate loaded into one of the three cameras used the finest meteor spectrum yet secured was photographed.

Up to the present only some forty meteor spectra have been photographed, and over three quarters of this number in the last five years during observational programs planned for this express purpose Let us see what these photographs reveal.

The most evident fact is that the light of all meteors arises from bright line emission with little or no continuous spectrum The major part of this consists of the atomic lines of neutral iron, though other elements common in meteorites also appear. Chief among these are calcium, magnesium, manganese, chromium and aluminum. In general it is the ultimate or low temperature lines

of the neutral atom which have been observed, thus giving evidence of a low state of excitation in the luminous meteor vapor A study of the relative intensities of the iron lines gives evidence of states of excitation corresponding to furnace temperatures in the range 1,700 to 3,000 degrees absolute. We must be careful not to call this the temperature of the iron vapor, as the latter is obviously far from thermodynamical equilibrium and the word temperature has no real meaning in this case

A further examination of the spectra photographed to date reveals that they may be grouped into two definite classes or types In the first, designated for convenience Type Y, the H and K lines of ionized calcium are the most prominent feature of the spectrum while the iron lines contribute most of the remainder of the light. In the second, Type Z, the ionized calcium lines are markedly absent and almost all the lines are given by iron Where the heights of the meteors are known it has been found that meteors of Type Y appear above an altitude of 50 miles while those of Type Z appear below this level It is significant that this altitude also marks the lower limits of the first ionized layer, the region of brilliant auroral displays, the region of noctilucent clouds and the zone of maximum frequency of meteors and their trains.

The difference in the type of meteor spectra is evidently owing to a difference in the degree or kind of excitation which produces the meteor's luminosity. The necessary energy arises from the high velocity impacts of the air molecules on the meteor which cause first vaporization and then excitation of the meteoric material. It is a well-known fact that the meteors with high geocentric velocity appear at the greatest altitudes Spectra of Type Y show evidence of higher excitation and probably correspond to the faster meteors. The average excitation of the iron vapor in Type Z is much lower, as would be expected for slower meteors.

The interest of the spectrographic investigation of meteors lies not only in the information it yields concerning the physical processes through which the meteors become visible but also in the assistance it renders in a study of the upper atmosphere which, for the present at least, must be studied indirectly by investigating the properties of phenomena which exist far above the earth's surface The most important of these are meteors and their trains, the aurora, radio waves and sound waves It is fast becoming evident that there is far more to learn concerning the upper reaches of the earth's atmosphere than was once thought to be the case. Every clue to its structure and properties is valuable, and the detailed study of meteor spectra is one line of attack that must not be neglected.

PETER M MILLMAN
DUNLAP OBSERVATORY,
UNIVERSITY OF TORONTO

THE SCIENTIFIC MONTHLY

MAY, 1936

THE EVOLUTION OF PHYSICAL CONCEPTS

By Dr. SAUL DUSHMAN

ASSISTANT DIRECTOR OF THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

THE content of physics, as well as of all the other branches of science, has changed radically since the beginning of the century. No one realizes this more acutely than those of us who, like the writer, began our scientific training three decades or so ago. I still treasure a copy of Atkinson's translation of Ganot's Physics. It is dated 1893, although I purchased it second-hand seven years later. As I glance over its 1,100 odd pages and compare the contents with a college text of the present day, I note with consternation that my undergraduate course in physics was sadly deficient. It contained very little or absolutely no mention whatever of most of the topics which are as familiar as the alphabet to the average student of physics in 1936.

Let us summarize briefly the new developments in physical science since 1895.

Roentgen discovered x-rays in that year, and Becquerel made his first observations on radioactivity in 1896. In 1902–1903, Rutherford and Soddy brought forward their theory of spontaneous disintegration of radioactive elements. The atom had lost its attributes of indestructibility. In 1897 J. J. Thomson first published the results of his investigations on the charge and mass of the electron, and shortly afterwards O. W. Richardson began his researches on thermionic emission, thus initiating an era which was to witness the harnessing of these electrons to the electromagnetic radiations which had been discovered by Hertz in 1887.

During the last decade of the nineteenth century refined measurements were carried out on the energy distribution in the radiation from a black body. These observations could not be reconciled with certain deductions from the kinetic theory of gases and statistical mechanics. In consequence, Planck was led in 1901 to enunciate his theory of energy quanta. The new suggestion received scant attention in spite of its application by Einstein (1905) to the interpretation of the variation with temperature of the specific heats of solids.

But in 1911 Rutherford put forward his theory of the nuclear atom; in 1912 v. Laue carried out his famous demonstration of the wave-nature of x-rays, and in 1913 Moseley published his investigations on the relation between x-ray frequencies and nuclear charge. All these observations and the mass of spectroscopic data, which had hitherto failed to find a satisfactory explanation, were now fused together into a beautiful conception by N. Bohr in 1913.

It is difficult for the present generation to realize the immense transformation in physical concepts which resulted from the publication of Bohr's papers. The idea of discrete energy states as the origin of spectral lines furnished a union of Planck's quantum concept and elec-

tromagnetic radiation. However, this new point of view raised what appeared to be insurmountable difficulties. Bohr used classical, that is, Newtonian mechanics to give us a model of an atom constituted of one or more electrons revolving in periodic orbits about the nucleus. But in order to limit the number of these orbits, as required by the observations on the relations between spectral lines, he had to bring in a so-called quantizing condition. Only those orbits can exist, he claimed, for which the angular momentum of the electron is an integral multiple of $h/2\pi$. The theory worked for hydrogen and ionized helium, but it required a tremendous amount of patching to explain the spectral behavior of more complex atoms. Bohr attempted to bridge the gap between his peculiar mechanics and Newtonian mechanics by means of his famous Correspondence Principle. But none of the mathematical physicists could even suggest a plausible theory for the behavior of the electrons in a helium atom.

Moreover physicists were confronted with another grave difficulty. Is light, or electromagnetic radiation in general, to be interpreted on the basis of the undulatory or on that of the corpuscular theory? The experiments of A. H. Compton in 1923 showed conclusively that in the interaction of x-rays with electrons the radiation behaves as if constituted of corpuscles having energy $h\nu$ and momentum $h\nu/c = h/\lambda$. On the other hand, these x-rays may be diffracted by a crystal lattice and they then behave as waves.

Physicists were thus confronted with a dualistic conception of the nature of radiation. But meantime the difficulties involved in the Bohr theory began to accumulate in spite of the valiant efforts of Sommerfeld and a number of theoretical physicists. In 1925 Goudsmit and Uhlenbeck showed that the electron must be regarded as possessing an energy of spin. This smoothed over some of the difficulties, but raised others. There arose a searching of the heart, as it were, which was reminiscent of that time five hundred years or so ago when the Ptolemaic system began to break up under its own weight of *ad hoc* assumptions. A French physicist, Louis de Broglie, boldly suggested (1925) that perhaps, after all, classical mechanics is not valid for atomic systems, that corpuscles which possess a momentum of the order of magnitude of h may not behave like Newtonian particles at all and that they may even exhibit the properties of waves. Thereupon an event occurred which was quite dramatic. Two American physicists, Davisson and Germer, showed that de Broglie's hypothesis was the very explanation which could account for their observations on the reflection of electrons from nickel crystals. Moreover, to add further evidence in confirmation of de Broglie's suggestion, G. P. Thomson repeated with electrons the same experiment which v. Laue had devised to demonstrate the wave nature of x-rays. Only in this case, what was proven, beyond the shadow of a doubt, was that if G. P. Thomson's father had not already found that the electron behaves like a little bullet, the son would have concluded from his experiments that the electron is a wave motion.

The physicists, like other intelligent human beings, have always had the intuitive feeling that any interpretation of nature must be monistic. It made them extremely uncomfortable, especially before their colleagues in the realm of philosophy, to be espousing waves on Mondays, Wednesdays and Fridays, as Einstein described it, and to think in terms of corpuscles on intervening days. Perhaps they needed a day of rest in order to reconcile this Jekyll and Hyde existence.

In this dilemma the physicists began to inquire, quite rightly, "What got us into this trouble?" Well, for one thing, we had tried to put into our theories more than we could ever test by observation.

It became evident that the Bohr model was too concrete It suggested too many questions that could not be answered. Bridgman designates them "meaningless questions." Perhaps that is why we discard so readily the naive stories of our childhood. The fairies and princes are so well drawn that when we begin to compare them with actual beings it is no longer possible to believe that both can exist in the same world.

Here we must abandon for a moment our historical order and go back to the period 1905–1915 in which Einstein formulated first his special theory, and then the general theory of relativity. To the layman Einstein's logic represents an "esoteric mass of abstract formulas" and a great deal of mysterious discussion of a fourth dimensional world. But for the physicist the greatest service rendered by the theory of relativity was this,—that it removed completely from scientific thought those arbitrary elements which Newtonian mechanics had transmitted to us, *viz.*, absolute time and space. At one swoop, the ether, that noun for the verb to undulate, was shown to be a completely unessential concept; and in place of the Newtonian concepts new ones were introduced by which mass, time and distance could be defined in such a manner as to be independent of the particular conditions of the observations.

No one has pointed out more clearly than has Bridgman in "The Logic of Modern Physics" Einstein's contribution in changing our attitude towards physical concepts. "It is a task," he writes, "for experiment to discover whether concepts defined in a certain manner correspond to anything in nature. . . . In general, we mean by any concept nothing more than a set of operations; *the concept is synonymous with the corresponding set of operations.*"

It is evident [he writes] that if we adopt this point of view toward concepts, namely that the proper definition of a concept is not in terms of its properties but in terms of actual operations, we need run no danger of having to revise our attitude toward nature. For if experience is always described in terms of experience, there must always be correspondence between experience and our description of it, and we need never be embarrassed, as we were in attempting to find in nature the prototype of Newton's absolute time. Furthermore, if we remember that the operations to which a physical concept are equivalent are actual physical operations, the concepts can be defined only in the range of actual experiment, and are undefined and meaningless in regions as yet untouched by experiment. It follows that strictly speaking we can not make statements at all about regions as yet untouched, and that when we do make such statements, as we inevitably shall, we are making a conventionalized extrapolation, of the looseness of which we must be fully conscious, and the justification of which is in the experiment of the future.

Bridgman wrote these passages in 1925–6 and the ideas which he expressed were agitating other minds as well. The difficulties inherent in the Bohr theory and in the dualistic theories of the nature of matter and radiation were apparently insurmountable. "Where do we go from here?" was the question uppermost in the minds of the leaders.

The answer, first perceived most clearly by Heisenberg and Bohr, is that this dualism is actually inherent in the experimental arrangements used, in the agencies of observation themselves. *The nature of the experiment controls the result actually observed.* The difficulty is, that we have always assumed that we could treat phenomena as something apart from the tools used in the observations.

When we measure a length with a meter stick, or observe the position of an oil drop through a telescope, we are justified in assuming that the act of observing has introduced no effects on the object of observation. Consequently, it is possible, in ordinary dynamical problems, to specify the instantaneous state of a particle in terms of its position (which we shall designate by x), and its velocity, v, or more accurately, its momentum, $p = \mu v$. From a knowledge of the forces

acting on the particle, it is then possible to predict its subsequent behavior, as, for instance, its position and velocity after any period of time, t. Such a prediction is valid because it is possible to make observations on the initial conditions without "spoiling" the results of the measurements.

> However [as Heisenberg has pointed out] this assumption is not permissible in atomic physics; the interaction between observer and object causes uncontrollable and large changes in the system being observed, because of the discontinuous changes characteristic of atomic processes. The immediate consequence of this circumstance is that in general every experiment performed to determine some numerical quantity renders the knowledge of others illusory, since the uncontrollable perturbation of the observed system alters the values of previously determined quantities. If this perturbation be followed in its quantitative details, it appears that in many cases it is impossible to obtain exact determination of the simultaneous values of two variables, but rather that there is a lower limit to the accuracy with which they can be known.

For instance, in the Bohr theory of the hydrogen atom, the motion of an electron is assumed to resemble that of the earth around the sun. It is assumed that we can measure both the position and velocity of the electron at any instant and that from this we can derive a magnitude which we designate as frequency of revolution in an orbit. But is it possible to specify position and velocity simultaneously for an electron in an atomic system? Heisenberg's answer is that it is impossible to do this. In fact, the more accurately we attempt to determine the position, the less accuracy we attain in the measurement of velocity, and *vice versa*. If we designate the uncertainty in the determination of momentum by Δp, and that in the determination of position by Δx, then it may be shown that there exists a relation between these two magnitudes of the form

$$\Delta p . \Delta x \geqq h \qquad (1)$$

This conclusion constitutes the generalization which is known as Heisenberg's Principle of Indeterminacy, and while it does not enable us to make any calculations on the behavior of atomic systems and electrons, it is extremely important in indicating the nature of the predictions which can be made about such particles.

Heisenberg's principle postulates that there exists a *fundamental limitation* governing the possibility of associating exact determination of position with exact determination of momentum, when dealing with such systems as atoms and electrons, and the reason for this is the fact that any observation on atomic systems or electrons involves an interaction with agencies of observation, not belonging to the system. Thus the *initial conditions* in any dynamical problem involving atoms are *indeterminable* to the extent defined by equation (1), and consequently we can not expect classical methods to be valid for calculating the behavior of a microscopic system such as an atom or an electron.

What, then, can be calculated with regard to the behavior of such a system? In the ordinary affairs we have learned to solve such problems by applying the methods of the theory of probability. In the case of atomic systems we can calculate only the probability of occurrence of any event, and the development of a mathematical technique for carrying out such a calculation has been the objective of the new quantum mechanics with which are associated the names of Heisenberg, Schroedinger and Dirac.

Now the most salient feature of this technique is its complete detachment from mechanical models. In the classical quantum theory a hydrogen atom in the normal state was represented by an electron revolving in a circular orbit about a nucleus of unit positive charge. But the new quantum mechanics merely postulates that there exists a field of force due to the nucleus, and then determines what is the relative probability for the occurrence of the electron in a unit volume at any point in the space

surrounding the nucleus. It expresses this probability quantitatively as the square of a certain function, known as an eigenfunction, and designated by ϕ.

One type of mathematics used in determining these eigenfunctions, that of Schroedinger, resembles formally the sort of mathematics used in the solution of problems involving vibrating systems. It is a well-known fact that an organ pipe, a string or membrane fixed at the edges can vibrate only according to a series of discrete frequencies. The different possible frequencies are given by ν_0, $2\nu_0$, $3\nu_0$, etc., where ν_0 is known as the fundamental tone. In a similar manner it is found by application of the new quantum mechanics that any atomic system can exist only in a series of discrete energy states, each of which is designated by three quantum numbers. Furthermore, these numbers are not brought into the calculation by any special quantizing principle. They arise naturally in the process of solution and may be regarded mathematically as defining the number of nodes along each of the three coordinate axes used to define the function ϕ. The discrete energy states are known as eigenvalues, and they constitute the mathematical analogue of the discrete frequencies which occur in the solution of problems for vibrating systems.

However, if we speak of this mathematical technique as wave mechanics, we must not infer from this that we are dealing with a physical reality. The term "wave" in quantum mechanics has about the same significance as its use in the expression "a crime wave." It is a convenient fiction, used to represent a magnitude which is a function of all the coordinates of the different particles constituting the system. For instance, in the case of the helium atom, the eigenfunction is a function of six coordinates, corresponding to the three coordinates required for each electron.

This conclusion regarding the nature of the eigenfunctions is also deduced from the fact that we can derive the same results by a purely symbolic mathematics which makes no appeal whatever to any physical analogy. This is the technique devised by Heisenberg and Dirac, which uses the algebra of matrices and operators. To attempt to explain this type of logic, in a discussion such as the present, is impossible. The important point is that this apparently non-sensical kind of mathematics leads to conclusions which are in agreement with the experimental observations on the behavior of atoms and molecules. The mathematics merely acts as a calculating machine. At one place we insert such fundamental relations as we know are valid experimentally; then we turn the crank, and after much manipulation and groaning of the gears, certain results appear, and they involve other relations which may be subjected to experimental verification.

Let me illustrate by considering the problem of the interaction of two hydrogen atoms. We know that each atom consists of a nucleus of unit positive charge and an electron. What happens when two such systems are allowed to approach very closely? We have, to start with, the fact that each of the four particles, the two electrons and two nuclei, exert forces of attraction or repulsion on the other three particles—and that these forces must vary inversely as the square of the distance between any pair. But we also know this—that because of the principle of indeterminism, it is impossible, when the two atoms are close together, to identify each electron with a particular nucleus. The electrons are constantly interchanging places, and by no experiment can we ever keep track of each electron separately. We now insert these facts into the Schroedinger equation, that is, the calculating machine, and proceed, according to definite rules, to manipulate the equation. The deductions that are obtained are quite novel. For one thing, we learn that there is only one chance out of four that the collision

of two hydrogen atoms will result in molecule formation, while there are three chances out of four that the atoms will collide elastically without molecule formation. Furthermore, it is possible to calculate the heat of formation of the molecule, and we find that electrostatic forces of attraction and repulsion account for only about 10 per cent. of this energy, the other 90 per cent. is due to what are known as exchange forces, because they arise from the possibility of interchange of the electrons in the two atoms. Thus, the homopolar or shared-electron bond expresses to a large extent this exchange energy, for which we can not find any physically satisfactory representation.

Another well-known illustration is the interpretation on the basis of quantum mechanics of the observations on the rate of disintegration of radioactive elements. In classical mechanics a particle at the bottom of a valley must certainly remain there until pulled out by an external agency. But in quantum mechanics, we find that if the hills surrounding the valley are not too thick compared with atomic dimensions, then there is a definite probability, if the particle has sufficient kinetic energy, that it will "tunnel" through these hills and thus escape permanently.

This theory of the penetration of corpuscles through potential barriers has made possible a quantitative interpretation of the rate of emission of alpha particles by the nuclei of radioactive elements, and has been applied in other fields with equally satisfactory results.

Perhaps you are now in a position to sympathize with our friend Alice:

> "I can't believe that!" said Alice.
>
> "Can't you?" the Queen said in a pitying tone. "Try again, draw a long breath, and shut your eyes."
>
> Alice laughed. "There's no use trying," she said, "one can't believe impossible things."
>
> "I daresay you haven't had much practice," said the Queen. "When I was your age, I always did it for half an hour a day. Why, sometimes I've believed as many as six impossible things before breakfast."

To an older generation, brought up on the mechanistic views of the latter part of the nineteenth century, all this new type of calculus appears incomprehensible. There is a popular belief that this cryptic symbolism is only a temporary phase in the development of a more comprehensible representation of nature, and even so great an authority as Sir James Jeans implies this opinion in his work, "The Mysterious Universe."

> The essential fact [he writes] is that *all* the pictures, which science now draws of nature, and which alone seem capable of according with observational fact, are *mathematical pictures*. Most Scientists would agree that they are nothing more than pictures—fictions if you like, if by fiction you mean that science is not yet in contact with ultimate reality. Many would hold that, from the broad philosophical standpoint, the outstanding achievement of 20th century physics is not the theory of relativity with its welding together of space and time, or the theory of quanta with its present apparent negation of the laws of causation, or the dissection of the atom with the resultant discovery that things are not what they seem; it is the general recognition that we are not yet in contact with ultimate reality. To speak in terms of Plato's well-known simile, we are still imprisoned in our cave, with our backs to the light, and can only watch the shadows on the wall. At present the only task immediately before science is to study these shadows, to classify them and explain them in the simplest possible way. And what we are finding, in a whole torrent of surprising new knowledge, is that the way which explains them more clearly, more fully and more naturally than any other is the mathematical way, the explanation in terms of mathematical concepts.

Perhaps we might be so bold as to suggest that the so-called shadows themselves may constitute the only reality we can ever attain. Indeed, if we were philosophically inclined, this would be a most opportune excuse for discussing the problem "What constitutes reality?" But I have an impression that the question may be meaningless from Bridgman's point of view, and that the old Persian poet's opinion still holds valid:

Myself when young did eagerly frequent
Doctor and Saint, and heard great argument
About it and about: but evermore
Came out by the same door where in I went.

Why should nature be patterned after those physical concepts which we have formed on the basis of a rather limited experience? That we have found certain representations to be useful in dealing with such dimensions, velocities and masses as we meet with in everyday experience, is no *a priori* reason that the same models and same mode of reasoning should be applicable when we are dealing with either cosmic or atomic phenomena.

It would, indeed, be much more marvelous if this extrapolation to both the infinitely large and infinitesimally small were valid. Since, however, it has been found that such an extrapolation leads to conclusions in contradiction with observations, why should we not recognize that nature is essentially complex and that concepts which have proven useful in one region of experience may have to be modified profoundly when we wish to describe other regions? However, we must demand that in passing from one class of phenomena to another class, the transition in concepts be not made abrupt that is, *per saltu,* but continuous. Speaking mathematically, we can not permit any discontinuities in the slope of the curve which represents any one aspect of natural phenomena.

Now it is of extremely great significance that the new quantum mechanics represents just such development of classical mechanics. For it may be demonstrated that for large scale phenomena, the mechanics of Schroedinger or Dirac yields solutions which are just as precise as those derived by Newtonian mechanics. In other words, as we proceed from microscopic or atomic systems to those which are macroscopic, the probability increases more and more that the constituents of a given system will occur in definite regions of space with well-defined velocities, depending upon the initial conditions and law of force which is valid for the particles.

It is in this sense that we can regard both the theory of relativity and the new quantum theory as representing an evolution of our ordinary physical concepts which enables us to carry out calculations in the region of the infinitely large as well as in that of the infinitesimally small.

The history of the progress of physical science during the past three centuries presents us with many developments which are similar in nature, if not in content, to those of the present. In the time available it is possible to consider briefly only one or two illustrations of this statement, but actually the number is quite large.

One of the most fruitful concepts is that of the kinetic theory of gases, which originated in the middle of the nineteenth century through the work of Clerk Maxwell and Clausius. The pressure of a gas is due to bombardment of molecules on the walls; the temperature of a gas is a measure of the kinetic energy of motion of the molecules. But note how from such simple concepts we evolve the more complex ideas of temperature as a statistical magnitude, and of distribution functions with respect to velocities and coordinates. From this there evolves in turn the whole of statistical mechanics, the principle of equipartition of energy and the notion of entropy as a probability function. And speaking of entropy, we are reminded of the allied concepts of free and total energy.

These concepts fulfil in thermodynamics the same purpose as the potential function in classical mechanics, and thus make the law of conservation of energy the bond between the science of heat and that of motion.

But let us consider further the path along which we are led by the kinetic theory of gases. We have spoken of the

principle of equipartition of energy. It proves a veritable "sesame" to the observations on specific heats of solids and gases, and even to the laws of black-body radiation. But, note, there are some discrepancies, slight at first, but increasing in magnitude and number as our measurements become more refined. What is wrong? And the answer comes at the threshold of our century with Planck's theory of energy quanta. The principle of equipartition, we find, is true in the limiting cases of high temperatures and low gas pressures. At lower temperatures and higher pressures we must modify our original concepts and introduce the new idea of energy quanta.

Hence arises the Bose-Einstein form of statistical mechanics, which achieves for radiation or light corpuscles what ordinary statistical mechanics accomplished for material corpuscles.

However, a difficulty arises when we come to apply statistical methods to the electrons in a metal. The Drude-Lorentz picture of a current in a wire as due to streaming little carriers, each loaded with a unit electric charge—this representation is very realistic, beautifully so, and works after a fashion. But the model leads us to wrong conclusions in many cases. We know that the electrons in a metal must behave as a gas at extremely high pressures. Furthermore, we know from the experiments of Davisson and Germer that electrons in motion also behave like waves. A reconciliation is found in the Fermi-Dirac statistics, which shows how the transition may be made between a statistics devised for ordinary gas pressures and high temperatures and another form which must be valid for low temperatures and very high pressures. Also, Bloch, Peierls, Bethe and others show that by the introduction of the wave concept certain other observations on the behavior of solids may be interpreted much more satisfactorily.

All these achievements have involved a constant extension of concepts which originally were intended to give us mechanical models of the phenomena about us. But gradually the concrete model has faded out and vanished, to be replaced by a mathematical logic in which all the anthropomorphic and subjective aspects no longer appear. Always the efforts of the great contributors towards the progress of science have been directed from one point of view—that of eliminating from our concepts their residual traces of animism, tradition and dogma.

There is a suggestion here upon which, in view of the present state of world events, we can not help but dwell for a moment. In fact, the noted historian, James Harvey Robinson, has written an essay entitled "The Humanizing of Knowledge," in which this thought has been developed in a most interesting manner.

Perhaps, the scientist may be a Moses crying in a wilderness of ignorance and prejudice, but is it not remarkable that science is the only activity of the human mind in which regimentation and dictatorial control of ideas have proven impossible of achievement? Because of this, it may yet happen that the world will be saved for liberalism and freedom of opinion by those unobtrusive workers in search of truth for whom the only ideal is

> But to live by law,
> Acting the law we live by without fear,
> And, because right is right, to follow right
> Is wisdom in the scorn of consequence.

Nature is complex, as mentioned already, and the only feature that is astounding about the whole of theoretical science is this: that human intelligence has been able to devise a method of reasoning with almost transcendental symbols by which a one-to-one correspondence is attained between the deductions

from this reasoning and the actual observations.

If, according to Bertrand Russell, "Mathematics may be defined as the subject in which we never know what we are talking about, nor whether what we are saying is true," then the greatest advantage inherent in the use of mathematical methods is their very generality and complete detachment from concrete visualization. The abstractness of mathematics enables the human mind to think in terms of concepts which transcend the limits of experience and thus opens up new possibilities for interpreting the interrelations of those magnitudes which observation reveals. It is not at all essential that these representations shall be physically comprehensible. For after all the only object of theoretical physics is to develop a set of concepts and rules of reasoning in terms of those concepts by which quantitative conclusions may be deduced. The object of physical science is not to answer the question "Why nature behaves as it does." Rather, it is the ultimate objective of science to describe the universe about us in terms which shall enable us to systematize the various observations and predict as accurately as possible the results of further experiments.

The history of physical science shows us the gradual development of such concepts as would prove most useful in fulfilling this purpose. The "Principia" of Newton, the "Mécanique Céleste" of Laplace and the "Thermodynamics" of Willard Gibbs are representative of stages in this evolution of ideas in which Dirac's "Principles of Quantum Mechanics" will assuredly not be the ultimate. These works, and others like them, symbolize the constant efforts of the human intellect to understand the universe about us—efforts which will not cease as long as man survives. For the greater the extent of the known, the more numerous do the unknown regions become which beckon us on.

Undoubtedly the near future will see further modifications of present concepts. We are just beginning to learn something about the nuclei of the atoms and their transmutations, and further discoveries will be bound to affect our present ideas profoundly. But whatever the future will reveal, of this much we may be certain, that our representations will not be in the direction of the mechanistic models of the nineteenth century and its philosophical attitude of determinism. Far from it. The study of mathematics has opened up many vistas replete with suggestions for new methods which physical science may appropriate and incorporate into its interpretation of the universe. Signs of such developments are not lacking even now, and if we regard the achievements of the past thirty years as a guide, then indeed we may look forward with confidence to even greater progress in the next thirty years.

LEPERS AND LEPROSY

By PERRY BURGESS

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In dealing with leprosy it is important to have in mind that there are two distinct problems involved. The first is concerned with giving food and shelter to people who are disintegrating into loathsome helplessness. The second, and by far the more important, is that which is concerned with finding the means of eradicating the disease itself.

It is generally accepted that there are not less than three million lepers in the world, and if we were able to detect all those in early stages the number probably would be much greater. Of the positive cases in institutions probably about 50 per cent. are incapacitated for work, and a pitiful handicap is placed on the others, since with a few exceptions the products of the leper's toil has no market. No well person wants that which his leprous hands may produce.

The leper's state, especially in the advanced stage, is such a pitiful one that tens of thousands of dollars and hundreds upon hundreds of kindly disposed lay-workers have been forthcoming to make easier the lot of old men, young women, little children, whose fate could, by no stretch of imagination, be more miserable.

I have visited some twenty countries where leprosy is found and in none of these did I fail to find something, and in many places a great deal being done by governments or private institutions, and in most cases by both, for the leper's physical needs. However, we have, in the main, only begun to work at *leprosy,* since probably not more than 2 per cent. of the world's total of victims of this disease are in any kind of leprosarium and too often these leprosaria are nothing but asylums, with no pretense of giving the inmate medical attention or of trying to get at the solution of the disease itself. It seems incredible, when one stops to think of it, that pretty generally we have thought much work was being done for leprosy if much money was spent on feeding and housing lepers. It seems tragic to see great numbers of lepers herded together and often not one thing being done for them medically; to see literally millions being spent for subsistence and often almost nothing for research. It is toward correction of that condition that we bend our energies.

I have visited leprosaria with as many as a thousand men, women and children stricken by this disease and not a single one of them receiving medical attention of any sort. In an isolated ward of a general hospital I saw a young man, who had been an inmate of one of the leprosaria and had pleaded that he be brought to the hospital so that he could be treated. From a leprosarium, mind you, and even so the treatment being given him was a method that had long been discredited by practically every modern leprologist. On the other hand, I visited one place in Southern China where the lepers had built their hovels among the tombs of a cemetery, as in Biblical times, using for materials frail and perishable branches of palms. In this place I found a clinician and a bacteriologist with modest but adequate laboratory equipment and examinations being made with care and intelligence. As an American I am proud to say that in the United States, where the total number of lepers is probably not more than 1,000 cases, there is maintained at Carville, Louisiana, the finest and best equipped leprosarium I have ever seen.

With twice as many new lepers developing each year as are now in all the leper colonies in the world, I'm convinced that the very fact that so much money is being spent to care for lepers often serves as an actual barrier to any considerable sum being spent in the more important basic studies of the disease.

It is much like attempting to win a war by the single expedient of hospitalizing the wounded. It is humanitarian and right to hospitalize the casualties if we can, but when a war is on the essential thing is to win the war and thereby prevent other casualties.

Segregation has been generally considered as the only means of eradicating leprosy, but with probably not more than 2 per cent. of the lepers of the world in isolation it must be quite obvious that segregation will never solve this problem. I do not want to be misunderstood in this matter of segregation. I believe thoroughly in it as welfare work, and where it can be practiced 100 per cent. it may prove an effective preventive measure. Norway and Sweden are frequently pointed to as countries where that has been done. However, I do not believe that the evidence is indisputable, that even in these instances segregation was the sole factor that led to the diminution of the incidence of leprosy since the disease has practically disappeared from all Europe where only seven hundred years ago there were not less than 2,000 homes for lepers.

One must admire the notable efforts being made in the Philippines and if that government can continue to expend the enormous sums for this purpose that have been spent in the past, reduced somewhat by establishing agricultural colonies, as is now being proposed, this will constitute probably the most thorough experiment as to effectiveness of isolating lepers from the well population that we have ever known. However, we are compelled to grant that after over thirty years of this heroic segregation there is no striking evidence that the number of clinically observable lepers has been decreased. In this same connection I wish to pay tribute to the campaign now underway in Colombia, where the government is making every effort to place all its lepers in a single colony. In this country it is even proposed to burn the houses in which leprosy has existed if a practical method of indemnification can be found.

As a world eradication program, however, segregation is both impractical and useless. How then can we proceed effectively against this disease that has been for centuries one of the greatest curses of the human race? I would urge the building in every country where leprosy is a serious problem of at least one central institution, manned by medical officers with sound scientific background. These institutions may have few or many patients. It is essential that there be enough for research. These centers should perform a three-fold service; first, carry forward investigative studies in the nature of the disease; second, make available to local doctors and institutions reliable information as to the best that is known with respect to treatment; and third, control the propaganda of the country to the end that it may be trustworthy.

We must bear in mind, however, in contemplating this problem that leprosy is a worldwide disease appearing under greatly differing conditions of life. There is, therefore, in my opinion, the necessity, in addition to what is proposed for the individual countries and what is now being done in many of them, for an international organization that will view the matter not from the peculiar conditions that exist in any one particular country, but shall study the facts of the disease as presented in different countries the world over. The Leonard Wood Memorial directs its activities

toward that phase of leprosy. The usual lines of research are being pursued by this and other organizations through individual scientists. We are carrying on bacteriological, pathological, clinical and biochemical studies. While believing that these fields of investigation are important and can not be neglected, they must, however, depend largely on individual inclinations and hunches. Something in addition is necessary. As a layman I can offer no opinion as to what may be possible with respect to other diseases, but in the case of leprosy I believe I am justified in the opinion that there is not only the possibility but the basic need for a thoroughly organized, centrally directed, worldwide, simultaneous, prolonged investigation of the environmental conditions of the leper—climate, food, social conditions, family history, contacts, etc. In other words, a worldwide epidemiological study of all the factors that, by the furthest stretch of imagination, could possibly contribute to the transmission of the disease. It must be clear that had such studies been carried on at any time in the past with respect to malaria, it would have been discovered that the anopheles mosquito was always present when there was malaria, and this fact would have led straight to the villain in the piece. Since leprosy exists under such varying conditions we must seek to learn whether there is not always some common factor present when people become lepers.

In my travel through leper countries two things have impressed me above all others. First, this matter of segregation already referred to and, second, the contradictions of conditions under which leprosy exists. I came to the conclusion that it was possible to make almost any statement about the disease and contradict it by actual example.

I suppose that the one belief that is most commonly held to be fact is that leprosy is not hereditary. Certainly the weight of evidence seems to be on that side.

I traveled one raw fog-ridden day up a winding river along low muddy banks in Southern China. What the English doctor accompanying me dubbed "Her Majesty's" barge, a small sampan propelled by two Chinese lepers, had been sent for us. We stepped ashore in the slippery mud at the boat's landing and were escorted through the old colony, that accommodated some six hundred lepers. A young Chinese boy carried my cameras. He did not look like a leper but, as owner of the cameras, I had some rudimentary interest in knowing whether he was or not. I learned that he was the son of a leper, was born in the colony, had been nursed by his leprous mother and lived in the lepers' dormitories. He had not contracted leprosy. Upon inquiry I was told that there were ten such in that one place.

In Southern China there exist entire leper villages, established by lepers driven from their own communities. They have not been permitted to marry people outside their village. I was told by American doctors that in some of the places it was impossible after three generations to find a single leper. Frankly I think this requires much more careful investigation, but apparently there has been a great decrease in the number of cases, whether it is true that the disease has entirely disappeared or not. It is noteworthy, however, that despite the fact that it has been for so long accepted that leprosy is not hereditary, several scientific workers are expressing doubt that this is true, and since the necessity for revising long-held beliefs in connection with other diseases is not uncommon, it is my opinion that the question of heredity must also be the subject of more thorough study.

Is leprosy easily contracted? The general idea of laymen is that it is highly

contagious. One of the kings of Angkor, that civilization which with its magnificent temples and palaces was for centuries swallowed up in the jungles of Cambodia, was a leper. I saw the statue of the old boy sitting disconsolately and alone on the terrace of the leper king in the city of Angkor Tom, his only companions the monkeys and birds by day and the prowling panther at night. The legend, told the visitor in all seriousness by the Sanskrit scholar who acts as guide, is that this king, returning through Victory Gate after one of his frequent military campaigns, was suddenly dragged from his horse and embraced by his leprous mother-in-law, who wasn't particularly enthusiastic that his majesty was getting a bit fed up with her two daughters and had added to the royal ménage a younger and handsomer wife. Leprosy is supposed to have assailed him with ghastly suddenness. At any rate, it is of interest that one of the Kymer kings was a leper, that he was driven from the royal palace to a special place built for him and that on the deep façade of this terrace there is seen among the sculptured figures of elephants and tigers and monkeys—a crabao tree, the native chaulmoogra, the nuts of which have offered a home remedy for leprosy in Southern China for hundreds of years.

While having a motion picture cutter in New York work on some film of the Culion leper colony, in spite of the fact that the particular print that he was working on was made in his own laboratory, before he would touch it he provided himself with cotton gloves—"just," as he rather sheepishly explained to me, "to be safe." On the other hand, last summer we had occasion to bring a leper to the office of the American Leprosy Foundation in New York City. Not one of the girls in our office had the slightest fear of this man, due, of course, to the fact that their work had given them a knowledge of the disease and how slight the danger of infection.

How justifiable is this great fear of contracting the disease? The case of adults becoming lepers is so rare that some leprologists are of the opinion that it is only contracted in childhood, an opinion that seems hardly justified, however. The last American to be a patient at Culion, for instance, was an ex-Spanish war soldier who had served in the Philippines. His leprosy developed several years later, and he advanced to one of the most shocking disfigurements it has been my misfortune to see. Cases are fairly common in which the patient apparently could have contracted the disease only after childhood.

The weight of evidence seems to be on the side of the opinion that leprosy is not easily contracted. I personally know scores of workers in the disease in every part of the world. The cases of contraction almost do not exist. The few cases that are known can easily be explained.

I visited a small and old leprosarium in Johore in the Non-Federated Malay States. Here were about two hundred patients. Until eight or nine years ago six or seven female nurses and workers, non-lepers, lived in the colony, ate with the patients and slept in the dormitories. Not one has contracted the disease. At Culion, where the leper population has numbered thousands since its founding in 1906 and is 7,000 at present, there has always been a large group of well people, doctors, nurses and others, numbering several hundred. Until very recently there had been no case of one of them becoming a leper. Quite recently a clerk who constantly handled money of the patients has become a positive case, but he had at least one relative with leprosy. In New York City we have twenty-five or so cases all the time and never a secondary case, not a single case, I am told,

contracted in the city. On the other hand, there are places where this disease, having gotten a foothold, has swept through the community like an epidemic.

One day I boarded an inter-island steamer to go from Honolulu to the leper station at Kalaupapa. The boy who had taken my bag around to the cabin which had been assigned to me came back to say that there was a woman in the cabin. When the purser investigated he found she had come over from Kalaupapa on the last trip and had occupied that cabin, and assumed that she was to have it on the way back. Since she had come from the leper colony I made inquiry as to who she was and discovered that she was the wife of one of the lepers and traveled back and forth regularly. Although I am not at all squeamish, going in and out of leper homes without any thought of possibly contracting the disease, at the same time I very generously said that this woman, so far as I was concerned, could occupy the cabin, since I did not intend doing so. It is interesting, however, that there was a case of a well person living with a leper and not contracting the disease, not an infrequent occurrence.

One of the most interesting conditions I have encountered was in Colombia, where there are about 7,500 patients in three leprosaria. These are all to be concentrated at Agua de Dios, which will then be the largest leprosarium in the world. To-day there are about 5,000 patients in this one institution. Until 1931 the law permitted a leper to bring his entire family to the leprosarium and a house was provided for him. To-day there are 2,000 of these well people, and in every case there is at least one leper living in the house, with no attempt made at segregation from the well members of his family. The only segregation practiced has been that the entire family was confined to the leprosarium and could go outside only with permission—a permission, however, that has been frequently granted. Practically no leprosy has resulted, actually a fraction of one per cent. of the population.

Why does leprosy occur in one place and not in another? We don't know the answer to that and if we did know we probably would be hot on the trail of the solution of the mystery.

Why in certain countries is leprosy found only in definite foci? For instance, in Jamaica most of the leprosy comes from two parishes, while in Puerto Rico it comes chiefly from three cities, and in Naguabo, the city from which most of the cases come, a large number of them occur in two streets in the poorer section of the city.

Why do we find it flourishing among the Malay countries; the Philippines, Java and the Malay States in about equal proportion?

Why do we find in certain places in Java low swampy country with much malaria and no leprosy and contiguous territory, high and dry, with no malaria and much leprosy?

Why is it that in certain provinces in Southern China one tenth of the entire population are lepers? Why is it that it is found in that country down in the heavy damp, low countries of the valley and the seacoast and in the snows of the mountains?

Congested population—is that it? Then why is it that with twenty-five or more lepers living at all times in New York City, it is said that there is not a case on record of an individual contracting it in the city? The answer is not racial. I doubt whether the Chinese of Singapore live any more crowded together than those in Chinatown in New York City or San Francisco. I am told that much the same conditions hold in London and Paris as in New York City, a few cases present all the time but no secondary cases.

Why do we find it assailing the Eskimos of Iceland and the Hottentots of Africa, or the Polynesians of the South

Seas? Why do we find it disappearing from Europe, where it flourished only a few hundred years ago and find still a million cases in China where its existence goes back to the beginning of history? Why is it that certain states in our own South have not a little of leprosy with a thousand cases in the entire country? Why is it that in 1856 170 Norwegian lepers settled in Minnesota and to-day the disease has practically disappeared.

We don't know. We only know that its locales are far-flung and differing, but up to the present we do not know the reason.

Is leprosy curable? Leprologists are very chary of the use of the word "cure," as are those who deal with tuberculosis. But progress of treatment has been so slow that until about two decades ago almost no leper had been released as an "arrested case." Now, from many institutions throughout the world increasing numbers are released each year. A discouragingly large number of these paroles relapse. In the Philippines about 3,500 patients have been dismissed during the last ten years as bacteriologically negative. The disease has recurred in about one half of these. Apparently this is not due solely, if at all, to the fact that these paroles go back into the same conditions of living as those from which they came. Very recently there has been conducted at Cebu an interesting experiment along these lines. Five young men, paroled from the Cebu leprosarium, have been taken into the home of a Catholic priest as house boys. This was done for the purpose of seeing whether sanitary living conditions and proper diet would prevent relapse. All these became positive again within a period of from four years to four months, except one. This latter after a two-year period is still quiescent, but this was practically a "burned out" case when paroled.

The most that we can say is that it seems very probable that arrestment has been effected in early cases, but we are a long way from having a specific for the disease.

At Carville, Louisiana, I was shown four lepers (children), all in one family. Their ages range from six to thirteen years. Six years ago the mother was diagnosed as having leprosy, which would have been just about the time the youngest was born. He presumably was in closest contact with the mother and was the heaviest case. The others varied according to their years, the oldest being the lightest. Also at Carville I talked with two women who had been negative for many years, the older one for fourteen. She and her sister have remained at the leprosarium as employes, since they have no other means of support. They were members of a family of nine, the father was seventy years of age, the mother fifty-eight, with seven children, whose ages ranged from twelve to twenty-seven years. When the woman who was telling me the story was quite young she married a man who was found later to have long been a leper. This man, upon their marriage, had come into their home and lived with the family. After four years he died. Within six years all the members of the family were in Carville as patients. An investigation on the part of the uncle failed to disclose that there had ever been leprosy in the family.

We think of leprosy as occurring usually among people of a low economic level. I was much interested to learn, however, from one of the leading dermatologists in Havana, Cuba, that in treating some 1,800 patients over a three-year period, patients drawn from middle and upper classes, he had discovered thirty-nine cases of leprosy. During this same period about an equal number were seen each year at the skin clinic of the general hospital, but only about one third as many lepers were discovered.

And so one might go on interminably pointing out facts which, at least on the

surface, seem highly contradictory. The question which I raise is, if such contradictions do exist, may they not be very significant? These very contradictions or seeming contradictions appearing under such independent and varying conditions possibly can be made to deliver into our hands that factor or those factors that must always be present when an individual becomes a leper, whether it is in Galveston, Texas, or Canton, China.

The foregoing facts, many of them mysterious and contradictory, are some of those that have influenced us to undertake the worldwide epidemiological campaign already referred to. We shall select as the director of this branch of our studies a man of unimpeachable scientific capacity. We shall determine, through the personal visits of the director, those strategic places throughout the world where units of investigation should be set up. This study will accept nothing that is not proved; it will overlook nothing that could possibly be the cause or a partner in the cause of leprosy. It proposes to conduct an epidemiological study in leprosy that for thoroughness will have had few counterparts in the history of medicine.

We will seek to know eventually, and we do not deceive ourselves by believing that any such program is a short one, just what the conditions were in Europe in the middle ages that do not exist to-day; what conditions exist in New York City that do not exist in Manila; we shall seek to know the habits and conditions of life of people stricken with this unspeakable disease.

From such a worldwide study, certain things must eventually come. Here and there facts will be observed that will suggest clues, definite leads for the bacteriologist, for the entomologist, for the biochemist, for the clinician.

Here too will be clearing houses of information and inspiration that inescapably will be felt in lifting the consciousness and improving the medical knowledge and practice in the various countries. It will be easier to at least bring information as to the best that is known and that one improvement, I can assure you from personal observation, would be worth all such a campaign will cost.

Originally this Leonard Wood Memorial was created in memory of a great American, for the purpose of erecting certain buildings in the Philippines and carrying on certain laboratory investigations. But almost from the beginning the opportunities and necessities have forced us into a wider field—the international field.

Now comes this program, bigger in its conception than the entire original purpose that brought this organization into existence, but a program we believe basic to the whole anti-leprosy campaign. This disease, that lays such hands of horror on little children, on fathers and mothers; that tears apart families and sends beloved ones into an accursed exile, shunned and abhorred by their fellows, was old when Hannibal led his army across the Alps and when Christ walked on the shores of Galilee. It stalks through scores of countries and through limitless centuries, a specter of loathsome horror, defying the power of present knowledge.

I believe that the American Leprosy Foundation, the organization of a country that knows little about the disease, has adopted a program that holds real promise.

We therefore to the extent of our financial ability will leave no scientific step untaken that holds any promise of finding the ultimate solution of this age-old curse of the human race.

IN QUEST OF GORILLAS

PART VII. THE LUALABA SHOW-BOAT

By DR. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

OUR exit from Albertville was rather hurried and undignified for the reason that our train, after keeping us waiting for two days, departed with exasperating promptness much too soon after dawn on September 28th Nevertheless we climbed on board a minute before starting-time, while our three boys wormed themselves into a howling mass of black humanity in the third class Here they soon allowed themselves to be robbed of their little roll of worldly goods, including their precious official cards of identification. Our train meanwhile departed with the usual warning shriek of the whistle and the excited babel of the attendant African public

Going westward, we went first through the little gorge where the Lukuga River makes off with the overflow from Lake Tanganyika Thus we were entering real territory of the Congo River Basin, which covers 1,425,000 square miles of tropical Africa.[1] The Lukuga is one of many hundreds of streams, large and small, that collect their tributes of water and earth in solution and pour them eventually into the mighty Congo The southeastern part of this river system as a whole curves from southeast to northwest, while the northern division, or Congo proper, runs at first northwest, then west, then southwest, picking up the Aruwimi, the Ubangi and other great rivers on the way The Basin is excavated in the great central African plateau, consisting largely of ancient granites and schists and constituting the mountains and highlands of the Cameroons, Gaboon, French Equatorial Africa, Angola, Northern Rhodesia, Tanganyika, Urundi, Uganda, the Sudan and Ubangi-Shari The plateau itself is the remnant of a Tertiary (Miocene) peneplain which was uplifted in Post-Miocene times.[2] The outlet of this gigantic drainage system is in the southwest corner; here the river expands into Stanley Pool, then, as it rolls off the high central plateau, it contracts into the falls and rapids of the lower gorge, breaking through the mountains of the west coast and flowing into the wide estuary from Matadi to the Atlantic

The floor of the Congo Basin dates back to Permian and Triassic times, since it consists in many places of fine sandstones, shales and clays, often horizontally stratified The successive series, the *couches du Lualaba* and the *couches du Lubilache*, are collectively equal to the Karroo series of South Africa[3] Some of these are commonly regarded as lake deposits, and in certain places they contain remains of fossil fishes that are allied with the Triassic fish fauna of South Africa and Australia. Even in that period, according to Veatch, there were local fault basins, which may appropriately be called early rift-basins, and they became filled with sediments containing "fish, phyllopods, and ostracods, the latter two in such abundance that in the Stanleyville region these little crustaceans formed layers of oil shales.

[1] J W Gregory, "Africa, a Geography Reader," 1928, p. 165.

[2] A. C. Veatch, Geol Soc Amer., Mem 3, p 161, 1935

[3] *Op. cit.*, pl. 9.

Photograph by E. T. Engle.
WAITING FOR THE RIVER BOAT.

These are the Stanleyville beds of the revised Congo nomenclature and are early Triassic.''[4] After the Upper Triassic there was an enormous hiatus in the fossil record of the Congo Basin, since there are no known fossiliferous deposits representing the entire Jurassic, Cretaceous and Tertiary periods, during which periods this great area stood above sea-level. In any case, it is certain that the modern Congo River system is relatively recent, since only in a few high places have its streams had time to dig down to the deep, underlying Proterozoic and Archaean formations which are so largely exposed in the highlands on the east.

A quite recent Lake Congo occupied part of the territory of the ancient Upper Triassic lakes[5] Only in relatively recent times was the brim of the basin so elevated that the lake spilled over at its southwestern corner and the present Congo drainage system began to develop as the lake itself diminished

Consequently, the central Congo rain-forest is for the most part a relatively new growth and the teeming animal life that it supports must have entered it from around the margins at no very distant geological date The chimpanzee, being a relatively bold, inquisitive, aggressive and adaptable animal, has conquered nearly all the forest territory on both banks of the Upper Congo and ranges from Uganda to West Africa. In spite of the wide geographic separa-

[4] *Op. cit.*, p 163.

[5] Pilsbury and Bequaert, *Bull. Amer. Mus. Nat. Hist.*, LIII, p. 545, 1927.

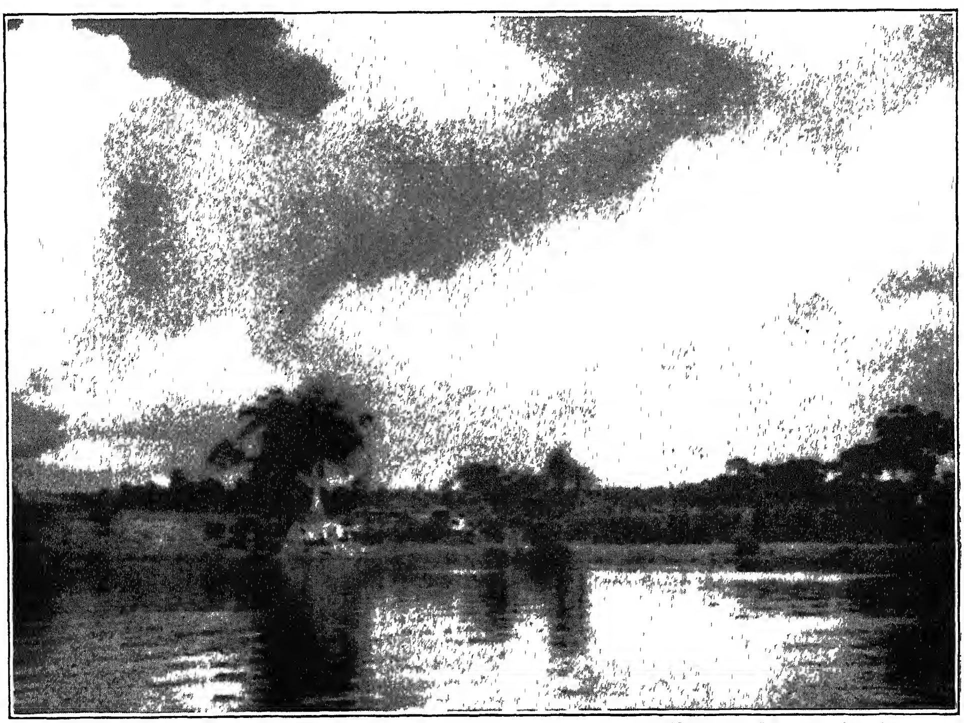
tion of the eastern and western gorillas, the two groups appear to be rather closely related species, as their characters merge into each other.[6] We do not yet know exactly how their dispersal from their original center or centers was affected by the presence of Lake Congo. Both the chimpanzee and the gorilla are closely related to certain fossil anthropoids, which in Miocene and Pliocene times ranged from Spain across France and Austria to India, so that the ancestors of the chimpanzee and the gorilla may have come into Africa by different routes from the north, but the eastern and western gorillas must surely have come from a common stock The eastern or Kivu gorilla, being especially adapted to live in the cool heights of the mountain forests and being an outlying member of a genus which has its headquarters in the forests of West Africa, may provisionally be regarded as an emigrant from that region.[7]

Late that afternoon (September 28th) we arrived at Kabalo and had our first view of the peaceful, muddy Lualaba River as it wandered northward on its way to the Congo. Here the river was flowing gently along a broad open flood plain with low hills in the background.

The porters who carried each of our fifty-eight pieces of baggage off the train and stacked it up on the boat pier gave vent to their feeling for antiphonal music.

[6] H. J Coolidge, Jr., Mem. Mus. Comp Zool., Harvard College, Vol. L, No. 4, 1929

[7] The alleged occurrence of forms that are intermediate between the chimpanzee and gorilla is very dubious; it is usually due to the fact that, with few exceptions, hunters do not know the most essential differences between the two. But of hundreds of chimpanzee and gorilla skulls that have been studied by qualified experts, no one has ever been recorded that showed really intermediate characters either in the molar teeth or in the nasal bones or in other features that easily distinguish chimpanzee from gorilla skulls



—*Photograph by J. H. McGregor.*

ALONG THE LUALABA.

"AdamanEEE," quoth Crosspatch, as he heaved up each steamer-trunk, gun-box or camp-roll.

"Nwoakoa," groaned Tatters, as the load settled on his tough old head.

I took a stroll about the straggling town, which included perhaps a dozen different shops or "trading posts," and was well rewarded by some choice bits. In the middle of the main square sat the skull of an immense elephant. This animal, I learned, had killed a black or two, the rest had retaliated by killing him, and after feasting on him and selling his tusks, they had set up his head in the market-place as a trophy. Next, I found a series of remains of native picnics containing grisly souvenirs of many old friends often studied in the museum but never before on their native heath: there was the parasphenoid bone of a huge catfish, together with fragments of its skull; here, the lower jaw of a succulent young hippopotamus; then the skull of a much larger and fatter hippopotamus, and lastly the bleached skull of what must have been an extraordinarily tough old buffalo. I took a little stroll in the open fields but could scare up only a few lizards and they ran under the roots of an old tree which must have died from St. Vitus's dance, so wiggly were its branches.

Our excellent dinner in the station agent's house was further cheered by some extraordinary large geckos, which persisted in running upside down on the ceiling, leaping at the flies and playing tag and hide-and-seek with each other with the utmost abandon and disregard of the law of gravitation If a house-gecko ever reflects on his human landlords, he must judge them to be curiously limited folk who are denied the freedom of the walls and the giddy joys of pursuing fat tarantulas and conducting topsy-turvy courtships on the ceiling.

In the evening we had to go to sleep on the seats in the train and let the mosquitoes bite us until the river-boat arrived late that night But our daily dose of quinine, taken ever since we landed in Africa, seemed to make us malaria-proof. Anyhow we were glad to get into our narrow but mosquito-netted beds on the boat

Early in the morning we started north, down the river. The steamboat was flat-bottomed with a surprisingly shallow hull; it was propelled by a rear paddle-wheel, operated by a big crank shaft on either side. The water was unusually low, so that we had to feel our way along the narrow channel; on either side of the bow a black boy took soundings with a long bamboo pole marked with red and white bands and called out the depth to the pilot, who could probably also see the readings from the pilot-house. Several times we anchored in mid-stream and sent out the black boatswain and his crew in a dingy to take soundings ahead; after receiving a favorable report we bumped and partly grounded but backed off, swung clear around and finally just managed to zigzag and pirouette through the shallows.

Here then we were launched at last on that mighty river of our imaginations, the Congo, or, as it is called in its upper reaches, the Lualaba. I was spellbound by its swirling, sucking whirlpools, its coiling trellises of interweaving ripples, its oily pools, its distant broad, flat surfaces that mirrored the tumbling white cloud masses of the African sky. In front of us are low rounded hills and the river swings to the right and then to the left leisurely to find its way around them The country on either side of the river is rather open, with few or many borassus palms In the distance the fully grown borassus trees show off well their narrow tall trunks, while their tops look like a compact cluster of palm-leaf fans, except that the borders are produced into long pointed tips The trunks are slender but with a curious long swelling, followed by a constricted zone near the top.

—Photograph by E T Engle

BORASSUS PALMS

The younger trees have large scales on their trunks and long pointed leaves A thick grove of borassus palms seen from a distance just before sundown is a beautiful sight, since the light from above is reflected from the trunks and produces a kind of pearl gray mist under the trees.

The destination of this section of our long alternating trip, first by train and then by boat, was Kongolo, where the Lualaba River again becomes unnavigable and all baggage and freight have to be transferred to the railroad link, which carries one north to Kindu. But in the leisurely manner of African travel we had to stay at Kongolo from soon after luncheon to very early the next morning, waiting for the train. We had the advantage, however, of retaining our cabins on the boat, which was tied up at the wharf, and of having our meals there.

Late that afternoon we four took a walk to the rapids of the Lualaba River. On the way we passed through a large native village with broad sandy streets, picked clean of all weeds. Possibly one reason why this practice is so widespread is that it may discourage ants, termites, jiggers, etc In front of the houses the men reclined, some of them in home-made steamer-chairs. I was told later that native steamer-chairs were first made in imitation of one that was carried by Henry M Stanley Their appeal to Africans is surely no less than it is to white men Here as elsewhere the palms are of great importance to the natives, since they furnish the main pillars, posts, uprights and horizontals, roofing and covering of their houses.

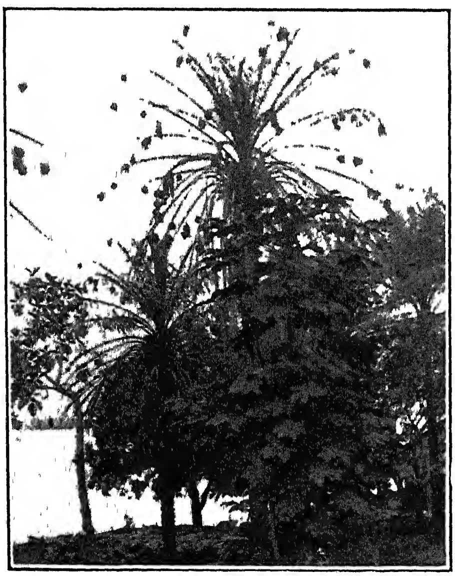
As we neared the river we passed over and between immense boulders containing mica. Evidently the ancient foundations of the continent lie near the surface at this place, so that the river has carried away the later formations Near the mission, however, I found some ledges of horizontal sedimentary rock, evidently of much later date than the old crystalline rocks of the rapids and probably representing the *couches du Lualaba* of the geologic map

At Kongolo we saw also the Catholic mission, with its substantial brick buildings; a "white sister" crossed the chapel yard and then we heard the people chanting vespers I wondered whether the natives conform to this religion in spirit as well as they do in letter; for notwithstanding its manifest outward advantages, its viewpoint and cultural traditions are naturally in conflict with their age-long traditions and ways of life

Returning to the boat for the night, we took the train early next morning

—*Photograph by H C Raven*
UMBRELLA TREE.
THE LEAVES SUGGEST NEBRASKA WIND-MILLS

and traveled in a northwesterly direction parallel to the river. Here for the first time we found ourselves passing through patches of the typical Congo forest, containing very tall trees mostly with fairly slender light trunks. At one train stop I snatched a twig from an "umbrella tree" (*Musanga*), one of the most abundant trees in equatorial Africa, the large leaves of which suggest a Japanese parasol which has been subdivided radially along the sticks. The trunk of a typical umbrella tree shoots up to a considerable height and then gives off a radial cluster of branches, which again divides and subdivides in much the same way



—*Photograph by H. C Raven.*
WEAVER-BIRDS' NESTS IN PALM.

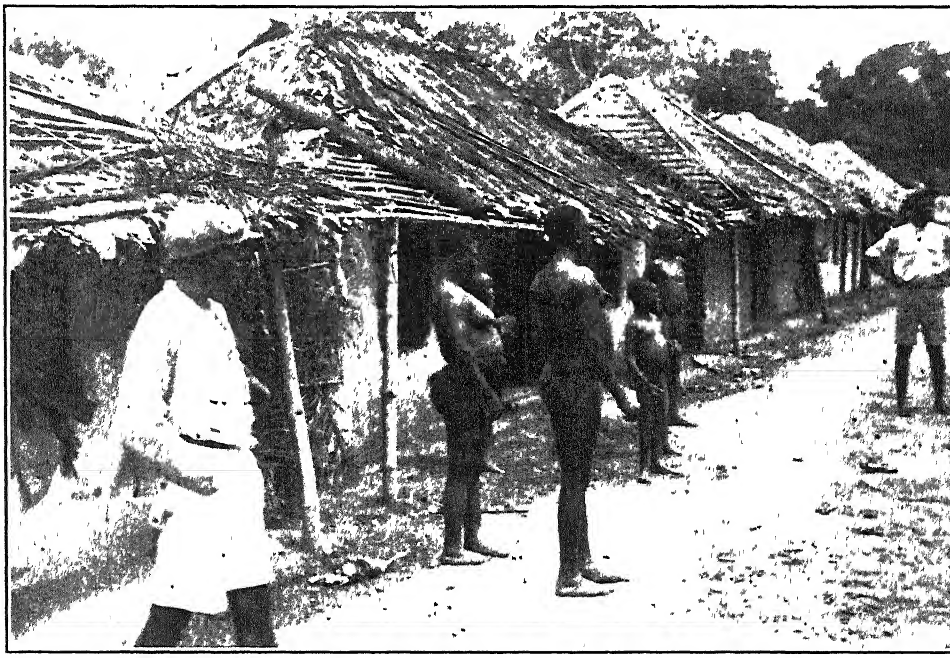
As we sat in the swaying dining-car at dinner that evening, a rather lively altercation broke out between two of our fellow passengers. A very stout and grouchy old person had had too much to drink and became fairly voluble, finally making some remarks that offended a lady Her husband loudly reproved the old man, who, however, was unrepentant and replied in kind The rattle of denunciations, sarcasms, expletives and other verbal musketry, which French and Belgians shoot with such deadly precision, continued until the old man grumbled himself into a doze. The train arrived at Kindu and we spent the night in our berths there. The next morning the old man, now sober and possibly regretful, must have apologized, for at luncheon the two men were very polite to each other as they sat at the long table on another river boat, where we all once more found ourselves

This stretch of the river was very wide and flat, the surface swirling with circles and great irregular oily polygons. On either side the forest was quite dense and we began to see native villages along the level banks. Every few hours we would tie up at a little settlement along the bank and take on a load of wood. In landing, a superbly developed black of the burly forest type would leap overboard near the bow, with a steel cable dragging after him; with a few mighty strokes he would swim to the bank, drag out the cable and tie up the boat Mean-

while another black would be doing the same thing at the stern Then a huge flat plank would be shoved out from the lower deck to the bank; a wooden horse would be placed under its farther end and a second wooden plank would complete the bridge. The white folks would walk off to see the local sights and some of the amusing black passengers would rush ashore to buy food, while others would come on board

While stopping for an hour at Wayika we were hospitably greeted by the Reverend Dr Whitehead and his wife, who have for many years conducted a mission at this place. Together they have compiled a dictionary and grammar of Bangala, the western dialect of Swahili This excellent work, two copies of which we purchased, is printed and bound in Mr. Whitehead's printing establishment by black assistants to whom he has taught the entire business of typesetting, proofreading, printing and binding. Here also are printed government reports and orders. This is an interesting example of what native Africans can do under wise management

Mrs. Whitehead told me an episode of their missionary work, which had recently taken place. They knew that some of their converts were still "worshipping idols" while also attending the Christian service So the good pastor called a council and told the natives that they must make a final choice between "the living Christ and a dead tree." After much discussion the natives declared which side they were on and brought a great wooden fetish made out of the trunk of a tree, which was supposed to be the dwelling-place of a powerful spirit. This was solemnly cut into small pieces and the pieces were then burned amid the acclamations of the people and the grateful prayers of the old couple.



—*Photograph by H C Raven*

MAIN STREET.

During the long hours of our trip down the Lualaba I amused myself by making crude sketches of the endless

panorama of the Congo forest. As I was utterly lacking in training the only thing in my favor was a strong urge to get the scene down in my notebook before it disappeared But naturally many technical problems arose, such as how to make a body of water look flat and yet show surface features, how to make limits for clouds that had none, what values to give to clouds, sky, river and forest, and the like With these puzzles to amuse me, the time passed all too quickly

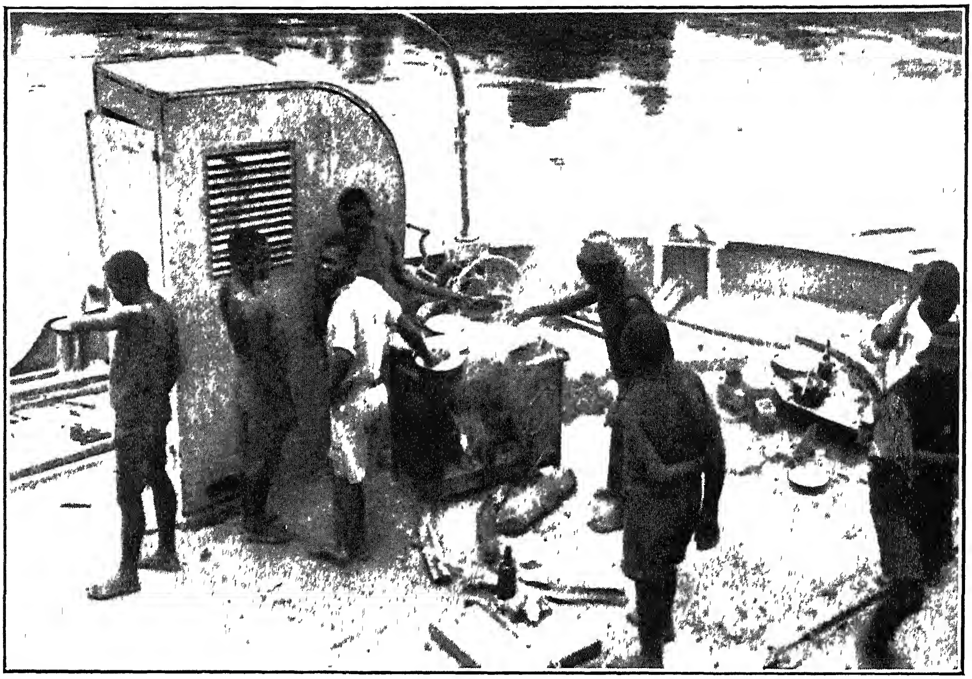
After about a day's journey north of Kindu the river became too shallow for our big boat to go any farther; so in the afternoon we tied up at a little village to wait until the next day for a much smaller steamboat that was being sent down from Pontierville to meet us.

Here then was my first opportunity to take a walk in the real Congo forest so I climbed up the steep river bank and, with Matambele trailing behind me, followed a small path that led through the village into the forest back of it. Here the trees were literally so high that one had to throw one's head away back to look at their leafy tops The forest was dim and silent except for the soft thud of a hornbill's wings and for its raucous call In a few moments I saw a slight stir in the treetops and then a small troop of monkeys fled with great leaps from tree to tree. Next we stepped over a train of ants, with many aggressive soldiers raising their mandibles in the air. Afterward we came across a single ant that was the Goliath of its tribe. One look at its mandibles confirmed my suspicious that I would not care to pass the night sleeping on the ground in that forest

Shortly before sunset we returned to the village, which consisted of a long row of mud huts on a high bank facing the river. Everybody was either seated in front of the huts or looking out of the doors Just at this time two men were paddling wildly about the river in pursuit of a tame duck that had escaped. They would try to head it off and zigzag toward it but several times it cleverly dived under the canoes just as the men got uncomfortably close to it. The village was all agog and every one found time to broadcast advice to the duck-hunters as well as to jeer when they upset But the duck had to reckon with an amphibious opponent, for one of the men paddled up close to it and then dived quickly from his canoe, catching it in a few strokes

Before the buzz of this excitement had died down the Nordic-looking captain of our steamboat strolled up. He was taking his wife's two immaculately white toy Spitz dogs out for an airing (the captain and his wife, by the way, had a regular palm-garden on the top deck of our steamboat) Then up came a yellow dog of the village to investigate. His advances toward these queer white strangers were peaceful enough but somewhat overfriendly "Grrrrr, spitz!" snapped the little rascals, visibly snubbing their poor relation. In the eyes of the human natives this display of superiority seemed to increase the value of the disagreeable canine visitors. One very old woman, whose loss of several fingers and toes had not dulled her sense of humor, asked the captain what price he would take for the pair "Ten thousand francs each, in advance," said he, and the bystanders yaw-hawed with a display of shining teeth that would be the envy of any salesman of American dental supplies.

The next day we were met by the small steamboat, which carried us over the rapids and shallows south of Lowa. But the only way that the contents of a large boat and a large barge attached can be dumped into one that is only a fraction of its size is by relying on the time factor, which has a very low value in tropical Africa. The small boat acted merely as a ferry to carry us a few miles to another big boat which had come down from Pontierville.



—Photograph by H C Raven.

PASSENGERS ON THE TENDER

This morning we thought that two of our boys (Poussini the cook and the round-faced, large-eyed Musafiri) had deserted, for they were missing We were wondering what they would do in this strange land, as they had been much depressed at being so far away from home But when we came up to the big boat there were the rascals still sitting in the wholly dejected manner of Jeremiah but waiting faithfully for us. They had been transferred in the first of the seven loads carried by the small boat to the big one

The big steamboats on which we traveled always had a load of third-class black passengers stowed between decks, behind the woodpiles and in front of the boilers These good people had paid their fares just as we had done and possibly at a proportionately higher rate, but aside from bare transportation it can hardly be said that they were getting much for their money. However, the miserable accommodations did not seem to discourage them in the least and every woman waited patiently for her turn at one of the two "stoves" where they could bake their native bread. But there was another class of passengers, traveling in a large metal tender, shaped somewhat like a canal-boat, which was tied to the port side of our steamboat. These people had the privilege of sitting on the deck of the tender, if they were lucky, or of stowing themselves around their baggage in the shallow hold They were for the most part either soldier police or gangs of road workers, usually with their families. As our staterooms and deck chairs were on the main deck above, immediately facing and looking down on these people, I could study them as much as I cared to without seeming to myself to be unduly rude and prying. For their part, the fact that they had no more privacy than the traditional goldfish did not appear to disturb them in the least.

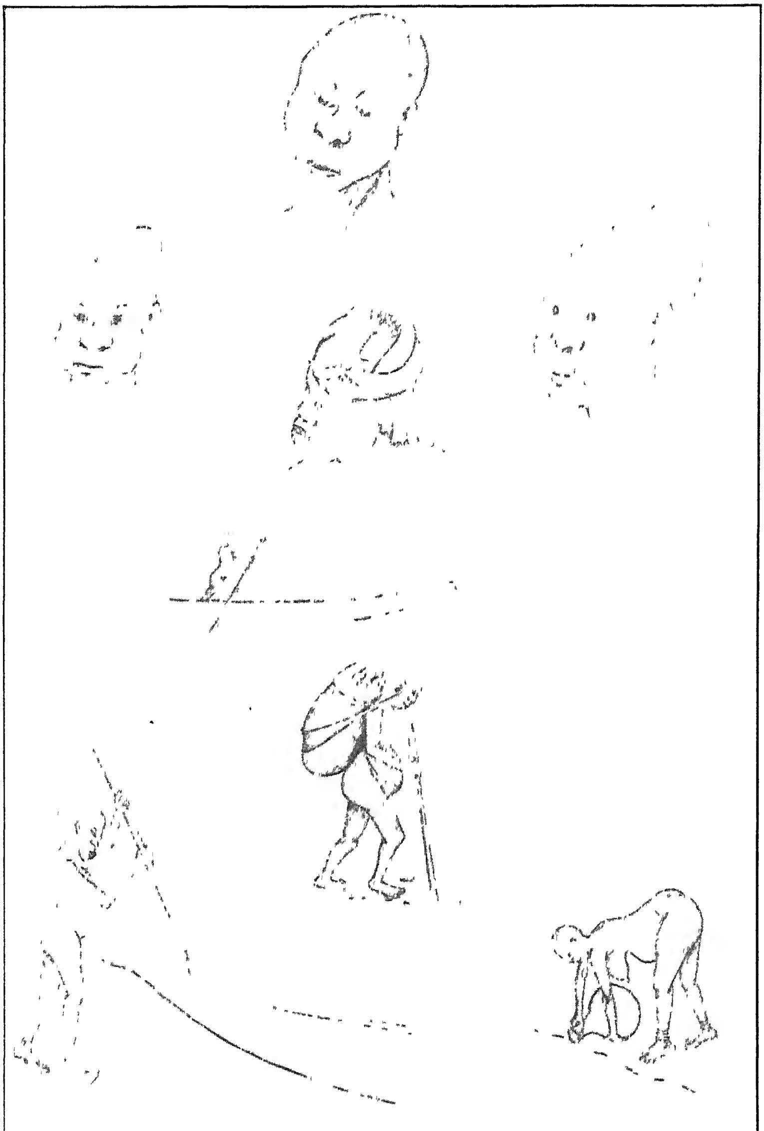
Probably most of these people were

either the children or the grandchildren of savages, who a generation or two ago had been greedy for human flesh and had practised horrible and revolting burial rites. And yet here they all sat huddled together like cattle in a hold, but in perfect peace and apparent good humor, exemplifying the doctrine of "live and let live" and not fearing either the violence of their fellow-men or the capricious vengeance of the gods Such are among the real benefits conferred by the benign but firm rule of the King of the Belgians

Signs were not wanting that the new Africa, copying the white man's ways, will have its social grades like any small town. For among the *hoi polloi* in the tender there was one dame of some distinction who sat as aloof as possible from the common trash; she was quietly dressed in gray, with a green parasol, and she spoke only to her handmaiden and to her husband. He, worthy man, was faultlessly attired in a Palm Beach suit, or its equivalent, and wore shoes. But remembering perhaps that he was after all of the same flesh and blood with his less fortunate fellow-passengers, he exchanged civilities with them, quite content to let his habiliments speak for him.

The domestic relations of the African families in our tender afforded some evidence that, however lazy he may be at home, the average *pater familias* is a real helpmate while on a voyage. As often as not the men took care of the small babies and one father of two tiny girls gave an amusing exhibition of forbearance. When the boat tied up at a wharf he took them both down to give them a bath. One infant sent up a fearful uproar the moment the water touched it, opening its mouth to an unbelievable degree and kicking and squirming. The father said not a word and neither frowned nor smiled, but went ahead in the most thorough way, bathing the baby on all six sides and conscientiously inspecting each little toe for chiggers. Then he gently set the still squawking baby down and began the operation on the other one. This one was very good and made no outcry. The father said nothing again; even when the job was finished he picked up one under each arm, came back to the tender and handed both to the mother without a word of complaint or comment Probably this man when a boy had served a long apprenticeship in the care of his younger brothers and sisters.

At one of the stations south of Ponticrville the scene along the bank where we stopped was quite theatrical High buff-colored bluffs were on either side of an open space and in the background a flight of steps carved in the earth led up to the village on top of the high bank. Brilliantly attired villagers were coming up and down the steps. A tall old half-Arab with beard and aquiline nose was standing haughtily on one side looking as grim and baleful as Milton's fallen Satan. But the chief figures were a group of belles, perhaps the most distinguished-looking lot I saw in Africa Some were passengers on our boat who had stepped off to greet their friends in this village. Several of the young girls had such mild and radiant faces that for the time being I even stopped admiring the superbly broad noses and semi-anthropoid mouths of the old males. But towering above these minor graces was a sable Juno with high cheek bones and a placid mien. She was easily first among the group and her gestures and expressions were unconsciously regal. Here was nobody's drayhorse but a woman wise in council and fitted to grace the household of a great warrior. It was remarkable how well these untutored feminine beings wore the flamboyant patterns of European make, which they had twisted into attractive turbans and mantles. Meanwhile several little boys, some of them with remarkably good wooden models of the river steamer, ran



Sketches from the author's notebook

RIVER FOLK

THE "SUGAR-LOAF" HEADS ARE PRODUCED BY HEAD-BINDING IN INFANCY

up and down the bank hoping to find purchasers, while others dived joyously for small coins or leaped for cigarettes thrown from the deck. Thus the passing show was continually dissolving into new and exotic scenes, which were brought to a close each day by sunsets of incomparable splendor.

> There the ponderous Lualaba,
> Flowing freely on its way,
> Moved with calm deliberation
> Without flurry or detention
> To its union with the Lowa
> And another flawless day.

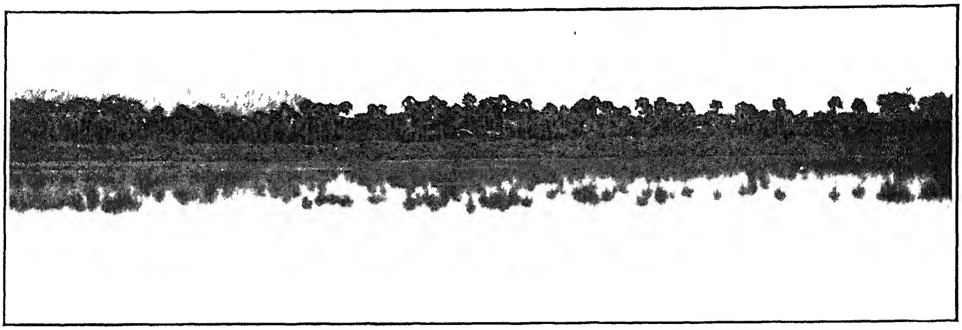
At one place where we tied up for the night was a small island, across which we walked. Many cheerful birds were there among the tall trees, especially parrots. On the other side of the island the shore was a cut bank of horizontally stratified shales, laid down by the ancient great lake of the Congo Basin.

During the daytime we were slowly passing the changing panorama of the leisurely Lualaba: now groves of stiff borassus palms in a great flat field; now thatched villages strung along the high steep bank, with many banana plants growing behind the neat houses, now the endless variety of the great forest with its many very tall white-trunked trees and its riotous bushes along the banks. In the river itself the muddy currents were always swirling and sucking as we came toward flat sand-bars or toward a clump of jungle on an island. Occasionally one could see in the distance the head of a submerged hippopotamus, but as a rule these beasts avoided the steamboats, where so-called civilized persons still delight in taking pot shots at them; once in a while by some mischance one finds the mark and raises a spout of blood from the voluminous interior of the poor leviathan of the rivers.

At another station south of Pontierville, where we took on wood and tied up for the night, I took a short stroll into the forest behind the village. The underbrush was not nearly so formidable as at Tschibinda and if one wanted to leave the path one could travel in almost any direction without using a machete. On the path I saw a large cylindrical thousand-legs, dark in color with red spots. Its tiny feet, projecting along each side in a continuous row, were moving in beautiful waves which passed along the body from rear to front. The beast was armored with circular segments of dark shining chitin. Perhaps it had been wounded somewhat, for several ants were investigating it, looking perhaps for a chink in its armor, but it turned and tried to seize them in its rather small jaws.

A little way farther along the path I saw a large and decorative spider with a brilliant red patch on its back and with long legs ending in hooks; it was in the middle of a huge circular web attached to a stem. I gently touched the web with my stick to see what the spider would do. Immediately it began to make the web vibrate with extreme rapidity and repeated this maneuver several times whenever I touched the web or made a swift whirring movement with my stick. Did it by this strange reaction increase its chances either of entangling the prey or of confusing the enemy?

In due time our boat tied up one afternoon at the wharf at Pontierville and all our baggage was transferred to the train for the last lap of our journey to Stanleyville. While waiting for our baggage I witnessed another example of the patience of natives toward their children. The soldier-police had disembarked from the tender and their wives were struggling up the grade with the baggage, small children and babies. One small child went far ahead and took the wrong turn of the path. The mother screeched at it in no uncertain tones, but when she overtook it she did not cuff it or beat it



—*Photograph by E T. Engle*

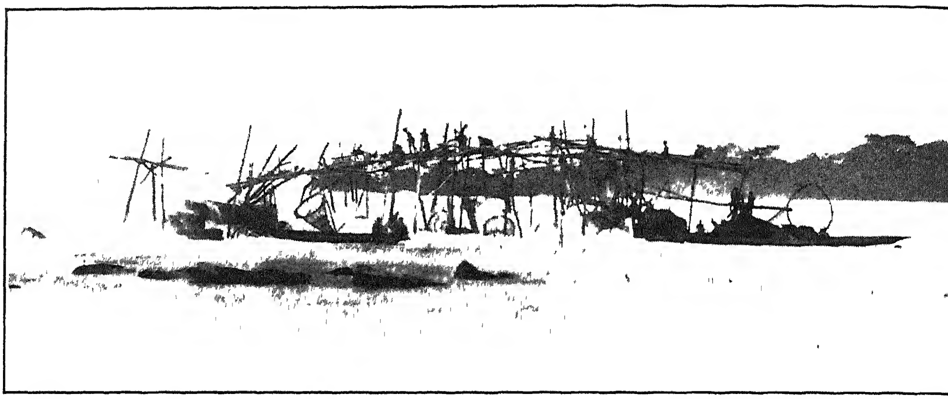
SILENCE.

but simply pushed it in the right direction and it yielded more or less gracefully. That seems to be their technique: steady pressure in the desired direction, while arousing as little opposition as possible.

Pontierville is rather a showy little place, a kind of botanical garden, with pebbly walks and many tropical trees, white shops and a red brick hospital. But at that time the forest was always calling me and I sneaked off to it in a few minutes After less than half an hour's walk along the railroad track away from the boat-wharf, I found an inviting path into the forest. At first there was nothing unusual, but after I had crossed a clear brook I heard movements in the trees and I stood quite still behind a trunk. A number of monkeys with conspicuous white spots across their faces and with long dependent tails that swung like pendulums were chattering and leaping about among the branches As they moved away I tried to follow them cautiously, but they soon caught sight of me and made off This was the best view of wild monkeys that I got anywhere in my travels.

After dinner on the boat we went aboard the train and settled ourselves on the leather seats for the night. The black engineer was fully conscious of his exalted and enviable position and as we passed through village after village his whistle shrieked a warning to the inhabitants, many of whom were lined up to respond with cheers and a clamor of greetings to the carload of natives in third class Our three black boys were in this car too and bearing up quite well under the circumstances. At first they had allowed somebody to steal their matting-roll, containing their tickets, medical certificates and precious employment books. Also, when only a week out from Uvira, one of them had expressed the opinion that we surely must be getting near to Europe. But by this time they were citizens at large and not taking any mutilated centimes from anybody, although still with the fear of the brass ring about their necks on account of having lost their credentials. In spite of the "poncho" or food money, each one would frequently come to sit dejectedly on the wharfs in front of us and would respond "Chukula hapana" (no chop) with an air of settled despondency which would have moved a wooden image to compassion and the disbursing of "matabish "

Next morning (October 5) it was with no slight joy (although the weather was still abominably gray and chilly) that we debarked on the shore of the mighty Congo River and looked across it to the widely extended city of Stanleyville This city is almost exactly in the center of Africa and only a few miles north of the equator. While waiting for the little river boat that was to ferry us and our



Photograph by Herbert Lang

A THRILLING BUSINESS—FISHING FROM A FRAIL BRIDGE BELOW THE FALLS.

baggage across the river. I had the pleasure of recognizing that the dark red sedimentary strata upon which we were standing probably represented part of the great Lualaba formation, which in many places rests on the crystalline rocks beneath. A few days later at the falls near Stanleyville I saw great ledges of this formation which had been cut through by the river. The natives also had evidently acquired the habit of collecting the slab-like pieces of this rock and of piling them like cords of wood into measured quantities marked by posts and wicker rods.

Arriving at Stanleyville we found the main hotel full and had to put up at a very poor second, where the food, rooms and service were as expensive as they were bad. That afternoon I started for the famous Stanley Falls southeast of the town, but by taking the wrong fork of a three-way crossing I finally found myself away out in the country. However, I did not regret the walk as I saw several things of interest that afternoon. In Stanleyville, like so many cities in the Belgian Congo, the excellent auto roads lead for miles in every direction and are lined by rows of oil palms. The road along which I walked had in many places been cut through enormous termite nests, which formed hills twenty or thirty feet high. First I went past the barracks, an extensive place where hundreds of soldiers live with their families in neat little rectangular houses of brick or of wood. Here was a great flock of noisy weaver birds in a high tree in the middle of the road. After I got outside the town I walked across a coffee plantation to the bank of a river that was flowing toward the Congo.

The most interesting thing I saw was a human footprint in a muddy road, at which I stared as if I were Robinson Crusoe looking at the famous footprint in the sand. This footprint was distinguished by the fact that the great toe was well separated from the others and the whole effect was considerably more ape-like than in any other foot I had seen among all the thousands I had looked at in Africa. I tried to follow this mysterious being, but as I am a very poor tracker I could find only a couple of places further on where the same footprint showed clearly.

> But at Stanley Falls the river,
> Roused to fury by duress,
> Lashed the rocks that barred its channel,
> Reared and plunged in its distress;
> Then with many a swirl and tumble
> And a thunderous roaring sound
> It descends into the Congo
> And comes out on quiet ground.

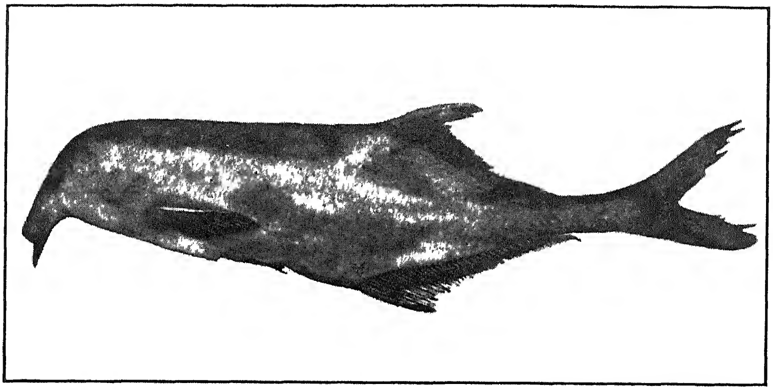
The next day Engle and I walked out to Stanley Falls, passing through a

native village of considerable interest, where the culture of the people seemed considerably richer than anything we had seen to date Here on top of a high hill was a huge drum, which could doubtless send its booming messages for miles in every direction Here also were many attractive household utensils, such as little carved bowl-like stools with a circular top and base, finely engraved canoe paddles and many fish traps and trawls, some of enormous size with a great circular opening and an immensely long tapering bag These were remarkably like the trawls we had used in deep-sea fishing on the Arcturus expedition of the New York Zoological Society (1925) and were assuredly an example of independent development Then we went down to the river and I had the joy of scrambling over immense ledges of dense dark-purple-red sandstone of the Lualaba series, apparently belonging to the same system as that I had seen at Albertville and Kigoma on Lake Tanganyika.

Another personal joy was a lot of fish-scales and fish bones scattered about on the rocks, first I found a boomerang-like bone with projecting points on its convex side, evidently the left preopercular bone of a large species of *Lates* (Nile perch); next, two hyomandibular bones, probably of the same individuals, next some fragments of the skull of a large catfish Meanwhile the ledges of sandstone were beginning to show some good potholes, worn by the whirling waters when the river was at flood, and a little further on these potholes became very numerous and of large dimensions so that they left a mottled surface like that of a gigantic Swiss cheese. There were also many enormous boulders of the same massive sandstone, which the river had tossed about as if they were pebbles We found that the easiest way to progress along this peculiar path was by leaping from rock to rock. This exercise happened to be an early pastime of mine and I was delighted to find that in spite of the passage of years I had retained enough of the simian joy in leaping to carry me safely over these rocky pitfalls

It is not to be supposed that two queer-looking foreigners could thus go leaping over the rocks and poking about in plain sight of the whole village, peering at empty holes in the rocks, picking up old fish bones and other inedible fragments, without arousing the suspicion that they must be in need of a guardian So pretty soon we were leading a procession of jabbering comic sketches, each of them volubly insisting that he and he alone should be and hereby was appointed to be our sole official adviser and guide, to conduct us hither and thither in the city of the great chief, and to receive all the rights, perquisites and emoluments pertaining to that office. I suppose it was discourteous, but we resisted and showed our firm intention of managing happily without any guide but ourselves

Among these funny ones there was a goodly number of black Herculeans with the grandest physiques one could find outside of a gallery of Greek statues. Very soon many more of these black gladiators swarmed down the rocks and got into a fleet of seven great war canoes, all standing with their paddles ready to start Then the unexpected happened, for they drove those huge forest tree-trunks forward into the roaring current, pushing them up to the base of the rocks below the falls and then letting go, so that the canoe dashed and swirled down the river with dizzy speed. Apparently they were not doing all this just to keep fit, but were somehow resetting the immensely long trawls that were already in the rapids. One wondered how the natives had managed to set up the many stout posts, just above the falls in the midst of the tumbling current, to which their weirs were attached Two little boys were standing breast-high in a side stream at the head of the falls and fix-



—*Photograph by the author.*

THE SNOOPING MORMYRID.

WELL-EQUIPPED TO INVESTIGATE EDIBLE TIT-BITS IN DARK CORNERS.

ing tiny weirs in a current that would have swept anybody else into the maelstrom. A man dived into the raging pool at our feet and swam about unconcernedly just to show off.

We found a small dead crab which we recognized as being related to those of Lake Tanganyika and soon many small boys were bringing us living samples, one or two of which we took home to McGregor. We made them understand that we did not want those crabs which had rudely shaken off their big claws (as they often do, apparently with the idea of paying tribute to the enemy that has captured them). We had already paid a franc to a boy for a perfect crab, but as he attempted to tie it up for us it broke off its own big claws. A man who had watched us then ordered the boy to give back the franc, as the crab was "no good." But we not only made the boy keep the franc (no great display of force being necessary) but also allowed the man to be our "guide" through the village at the cost of another three cents. If either of us has any Scotch ancestors in heaven, they must have groaned many times over such recklessness on our part.

One morning I got up very early and went to the market, taking Matambele, our chief comic artist, to conduct nego-

—*Photograph by the author*

POLYPTERUS AT LAST!

AUTHOR'S OWN SPECIMEN. THE FEATHER-LIKE STRUCTURE ABOVE THE PECTORAL PADDLE IS A "BALANCER" OR EXTERNAL GILL

tiations if necessary. What a treat to find among the fresh fishes a silvery characin, an elephant-headed mormyrid and the very reverend *Polypterus!* In my agitation the negotiations got a bit involved between the owner, Matambele and myself, it appeared at last that I was under the painful necessity of leaving one of these treasures, as Matambele had meanwhile spent most of my metal francs on vulgar food. As rapidly as possible I appraised the scientific value of each of these beauties, which to me at that moment far transcended that of all the sordid metal francs in the Belgian Congo. The characin's claim to distinction was that, according to many authorities, he is a descendant of ancient immigrants from South America, which had crossed along the freshwater streams of an ancient land that once extended from Brazil to Africa And whether or not this geological fish story be true, the characins are well worthy of an ichthyologist's respectful consideration

The mormyrid was worthy of preservation not only because the Egyptians had figured him nibbling at the body of Osiris but also because on his own account he was one of the queerest inmates of that fishy madhouse which has somehow been turned loose in Africa

About *Polypterus* of course there need not be an instant's hesitation For this heir of all the ages was the lineal descendant of the earliest vertebrates that had tried two dangerous experiments of the utmost importance to us: first, they had begun to sniff their oxygen straight from the air; and second, they had embarked on the greatest real estate transaction of all times, namely, the conquest of all the lands on all the continents, which up to that time had been held exclusively by twelve-inch cockroaches, scorpions and other bad citizens

While I was absorbed in these pleasing reflections, perplexed as to the choice between the characin and the mormyrid

—Photograph by H C Raven

CLOUDS AND WIND OVER THE LUALABA

OPEN-BILLED STORKS FLYING ABOVE THE RIVER.

and oblivious to the uproar about me, providence decided the matter in a manner very favorable to me, because a corpulent negress made off with the characin under my very eyes, leaving the long-nosed mormyrid and the *Polypterus*, the cost of which exactly equalled the small number of francs still in my possession. After these holy relics had been duly admired and photographed, they were reverently embalmed and laid away in the formaldehyde tank.

One day while we were in Stanleyville McGregor and I, besides going to the Falls already described, called upon Monsignor Grison, the head of the Catholic diocese at Stanleyville, who had made an extensive collection of rocks, minerals and other natural history products of the vicinity. He received us most graciously and showed us his collection The fossil fishes are of great importance because they indicate that parts of the Lubilache formation, which covers a great part of the Congo Basin, were laid down in fresh water, and because the fishes themselves belong to groups that were characteristic of the Triassic age in other parts of the world and suggest a corresponding age for this great inland lake.

Monsignor Grison also told us several facts of interest about the natives of the vicinity, which at the time of his first coming to Stanleyville, about thirty years ago, still practised cannibalism, at least occasionally In response to our questions he said that most of the grosser forms of superstition had been done away with, but that some of their own converts sometimes lapsed into witchcraft. We were told by others that the "Leopard Society" probably still existed in secret, and we had seen a mounted group in the museum at Terveuren, Brussels, representing a dramatic murder by members of this choice fraternity. When a certain man is judged to be worthy of death, the members of the society, disguised in leopard skins, meet him in a lonely spot in the woods The "leopards," who wear sharp claw-like knives on their fingers, then pounce upon him and kill him They then stamp carved leopard's feet on the path, either as a sign that leopards killed him or as a warning to others to beware of their vengeance. Some years ago, however, the Belgians discouraged this picturesque ceremony by hanging an entire chapter of the order.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month)

THE BIOGRAPHY OF AN ANCIENT AMERICAN LAKE[1]

By DR. WILMOT H. BRADLEY
GEOLOGIST, U. S. GEOLOGICAL SURVEY

As in olden times, when Kublai Khan held absolute rule over a vast domain and progressively amassed great wealth by reason of the tribute that flowed in from outlying provinces, so in a far remoter epoch, long antedating human history, a great lake held sway over a vast area in the Rocky Mountain region and gradually accumulated in tremendous volume a potential natural resource derived from the sun's unfailing supply of energy and from the mineral burden that flowed in from adjoining lands through its tributaries

So remote was this epoch that could we go back to it in time we would be compelled to gage our progress by the slow evolution of animal life and the gradually changing expression of the earth's face. We would have to go backward with undreamed-of speed past a pageant of animals that inherited the earth in slow succession as evolution molded them. So short is man's history that it would flit by too quickly to be perceived. Passing backward in a brief moment through the silent ice age, we would see man's primitive ancestors, together with giant sloths, giant bears and beavers and the woolly mammoth. Farther back we would meet small elephants and, on the plains, bands of horses, wild asses and camels. Farther back in time's flight we would find their smaller and ever smaller precursors. Suddenly would appear the hippopotamus-like titanotheres and a host of other strange creatures, each leading a succession of smaller and less specialized ancestors Finally we would come to the time of the diminutive four-toed horses, which dwelt in the forests and grassy parks of that epoch of long ago when the ancient lake came into its regency.

This great lake, known as "Lake Uinta," occupied a long, shallow basin or downwarp of the earth's crust about a hundred miles southeast of Utah's present Great Salt Lake. The record it left is preserved in the form of an immense body of nearly flat-lying beds or layers of fine-grained rock similar to lithographic stone. This great body of rock is as long as Vermont but considerably wider, and in places it is almost a mile thick Deep canyons and wide valleys are now cut through it in all directions, so that the whole record is accessible. The thin layers thus exposed bear a remarkably close resemblance to the leaves of a book. Indeed, it is more than a superficial resemblance, for the layers are in fact pages upon which are impressed symbols that portray events of that age so long past.

Modern books are so familiar that we take little thought of their construction and have no difficulty in reading their meaning. But when the earliest written records of man were found they could be read only after learning how the symbols were formed and what relation each bore to modern language So it is with the record left by the ancient Lake Uinta. Geologists in the seventies of the last century pried apart the stony pages and found that they contained a story about an ancient lake. But the story could be read no faster than the science of geology grew and provided the keys for inter-

[1] Published by permission of the Director, U. S. Geological Survey

preting the symbols. Moreover, the reading was slow because fragments of the record came to light only piecemeal as exploring geologists penetrated more and more deeply into those parts of the arid West away from established routes of travel. And finally, long passages in the text remained obscure until the study of modern lakes revealed what was taking place in them, for the characteristics of an ancient lake can be understood only by analogy with the lakes of to-day. Thus only recently, as more and more parts of the story have been assembled and integrated into an ordered sequence, has it been possible to learn how complex and varied is the history of Lake Uinta That history includes a wealth of information, not only about the plant and animal societies that dwelt in the lake itself and on the adjacent land, but also about the ways in which they changed to meet a gradually changing environment. It tells how for thousands of years the lake kept a sort of calendar, by depositing each year a thin layer of peculiar sediment that was sharply marked off from the layers formed the year before and the year after. Though these annual layers do not continue through the whole record, it has been possible from them to estimate that Lake Uinta was in existence for millions of years. The history is more than a recital of elapsed years, however, for it tells both of major catastrophes and of such trivial incidents as the migration along the water's edge of a swarm of small, swollen-headed larvae which, had fate been less harsh, would one day have split their skins and emerged as adult gnats. From this emergence, however, they were prevented by a drop in the lake level, which left them to perish and dry in the sun until the water rose again and deposited on their remains a shroud which it fashioned out of minute interlocking mineral particles.

I

In the beginning the site of Lake Uinta was a broad, nearly level alluvial plain—a sort of huge amphitheater, bordered on three sides by mountains but open to the south. Streams from the mountains wound listlessly across the plain and rested in the grassy marshes But this landscape was destined to change, for, beneath the plain, the stony shell of the earth was beginning with subtle slowness to warp downward. Thereafter the streams spread broadly over the meadows, changing them to lakes. At first there were two large lakes, but as the downwarping continued these soon expanded and coalesced into a single sheet of water as long as Lake Ontario but much wider Thus Lake Uinta came into being

Up from the north shore rose the great swelling bulk of the Uinta Range, its flanks green with forest. This forest may or may not have its counterpart living anywhere in the world of to-day; nevertheless, it must have been much like the forest that would develop on the southern slope of a high mountain on the present Gulf coast of the United States, could we but conjure up a mountain in that region. Just as such a forest would have different kinds of plants growing at successively higher levels, so it is probable that the forest which clad the Uinta Range in that ancient epoch was also zoned according to the altitude Fossil leaves, flowers, seeds and even pollen grains collected from the bottom deposits of the ancient Lake Uinta enable us to reconstruct the probable floral zones of a landscape that existed during the Eocene epoch more than 30 million years ago.

At the water's edge grew bur reeds, rushes, water milfoils and the familiar purple-spiked pickerel weed. But upon the shore and the wide flats adjacent to it grew trees whose nearest relatives—japonica, figs and a variety of aromatic

shrubs and trees—now live in the warm-temperate parts of the earth Vines, very similar to if not identical with our modern grape, grew along with gourds, delicate climbing ferns and the less inviting cat briers Where the bottom lands were sandy, palm leaves cast their slatted shadows on the ground

If we could have gone back through the swampy bottoms we would have found, among others, mimosa trees and trees related to the cinnamon growing with a large variety of ferns and evergreen shrubs. Pushing farther into the drier foothills, we would have passed through woods of oak, maple, hickory and gum—woods nearly indistinguishable from the present hardwood forests of temperate North America Higher up, pine and hemlock supplanted these familiar hardwood species, and in the highest parts of the range forests of spruce and fir predominated That the evergreen forests were remote from the ancient lake is attested by the fact that only one seed and the tip of one twig of these species have ever been discovered in the lake deposits, though leaves of lower-zone types are found there by the hundreds. Nevertheless, forests of pine and spruce flourished; their former presence is manifested by an abundance in the lake deposits of their odd pollen grains, each of which is fitted with two bulging air sacks that aided it to float many miles from the parent tree.

The insects, too, resembled rather closely those now living. Caddice-flies, whose larvae build about their bodies little masonry houses of sand grains or well-joined "log" houses of tiny twigs, frequented the shallow water at the lake's margin, together with the more familiar dragon-flies The wobbly-legged crane-fly was there with his diminutive cousins, the midges Beetles, crickets and the homely grasshopper were common, but if there were butterflies and moths they have left no trace.

INDEX MAP SHOWING THE LOCATION AND APPROXIMATE EXTENT OF THE ANCIENT LAKE UINTA.

Animals coming to the lake shore must have found it a disagreeable experience, for there they met clouds of mosquitoes, black flies and gnats, and larger flies that bit savagely. Spiders and the lowly cockroach have been found, and even one mite, which, incidentally, has the distinction of being the most ancient mite in North America—America's oldest louse, if you will.

Crocodiles shared with various river turtles the sluggish parts of the streams near the lake Land tortoises, rivaling in size the famous ones from the Galapagos Islands, plodded through the sandy lowlands. Snakes, too, there were; indeed, the most nearly perfect fossil snake ever found in the Western Hemisphere came from these lake beds. Water birds, like the loons, sandpipers and rails, must have been numerous, for impressions of feathers are common on the slabs of rock that were once mud flats bordering the lake. Of the birds themselves we know next to nothing—fossil birds are *rarae aves* indeed Oddly enough, however, the one remarkably fine fossil bird that has been found in

these lake beds was a native of the uplands similar to our ruffed grouse.

Despite the modern aspect of the forest that encircled ancient Lake Uinta, the warm-blooded mammals that lived in it were decidedly strange. Particularly striking was the ancestor of the modern horse, for it stood no higher at the withers than an Airedale pup. Its back arched somewhat, and instead of one hoof to the foot it had four slender hoofs on each front foot and three on each hind foot. These hoofs, however, bore less of the animal's weight than did a pad at the base of the toes The teeth of this primitive horse, unlike those of its modern descendant, were adapted to feeding upon leaves and soft, lush plants, for the West at that time was green with forest and meadow. Only through the following millions of years did it become the semi-arid region that we know to-day.

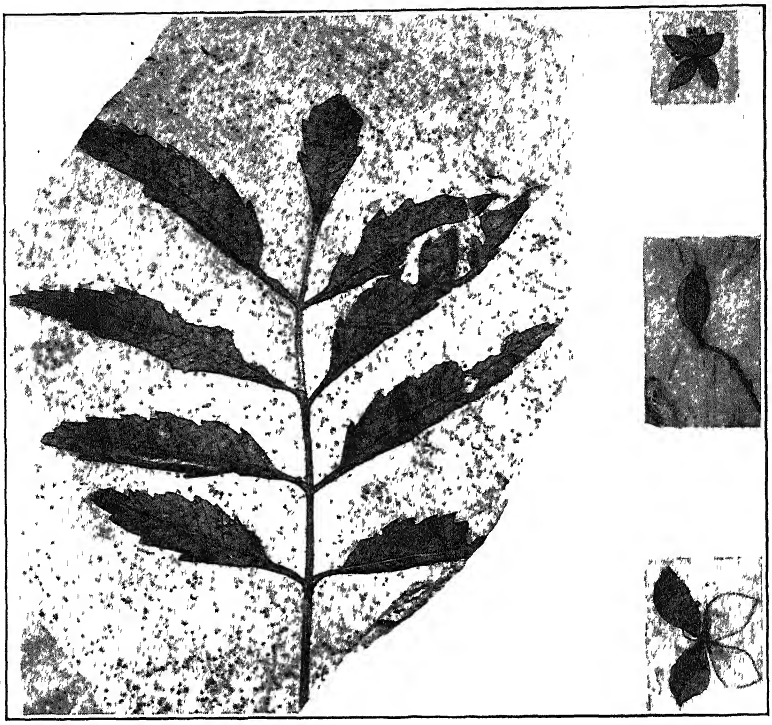
A fisherman peering down through the clear water to see what manner of fish there were among the pond weeds would not have been disappointed. Perch and other fresh-water fish inhabited the weedy bays, but they were greatly outnumbered by varieties of herring. To-day, most herring live in the sea, though a few go up rivers to spawn and a few others live in rivers. Thirty million years ago more varieties apparently went into fresh water to spawn, for those found as fossils are of two sizes—fry that had not long left the spawning ground and adults that had presumably returned from the sea to spawn. Least to be expected so far from their usual marine environment were the large sting-rays. The occurrence of so many forms that spent part of their lives in marine water implies that for a long time a perennial river ran from Lake Uinta to the sea, even though the lake was probably 600 or 800 miles inland. So great a distance from the sea would not have precluded intermigration, for salmon are known to travel more than 2,000 miles up the Yukon to spawn.

II

By the time Lake Uinta had become thus well stocked with fish it was a mature lake, for it had already been in existence more than a million years. Now as lakes grow old they, like men, acquire stores of worldly goods. So it was with Lake Uinta; as it advanced in age its waters became increasingly rich in foodstuffs. And, like a benevolent monarch, the lake gave all this increasing wealth for the good of its subjects—the varied and extensive aquatic population.

The life of a populous lake is a complex society, the members of which are interdependent. Most elemental are the microscopic plants and animals that float freely in the surface waters and derive their nourishment and energy directly from the sunlight and the dissolved salts. Upon the abundance of these minute creatures depends the very existence of other life in the community, for they are the ultimate source of food. Successively larger animals—the fairy shrimp, the water flea and the highly mechanized wheel animalcules—feed upon them and in turn are fed upon by small fish.

At this mature stage of Lake Uinta these tiny specks of life found themselves in a congenial environment, where food abounded and the temperature was most agreeable. They flourished in the midst of plenty and, late in the summer, when the water had been thoroughly warmed, literally took possession of the lake. Their numbers increased at an astounding rate; they clouded the water, then turned it a fulvous green, and finally covered it with a green scum, which the wind parted into lanes where the water might ripple again and reflect the blue of the sky. From beneath this surface stratum, filled with life, those organisms



LEAVES, FLOWERS AND A SEED

WHICH BELONGED TO DIFFERENT PLANTS THAT LIVED NEAR LAKE UINTA MANY MILLION YEARS AGO.

that had grown weary of the struggle for existence floated gently downward and sought rest in the quiet depths. So vast was the number of these weary motes that, despite their microscopic size, they bulked large in the total volume of sediment that reached the lake bottom Indeed, these late summer epidemics gave rise each year to a distinct dark layer of organic substance. It was partly by means of these organic layers that the ancient lake recorded the passing of the years. But there would have been nothing to mark one layer off from another formed the following year or the year before, if it had not been for a different kind of sediment, which accumulated more or less continuously throughout the year.

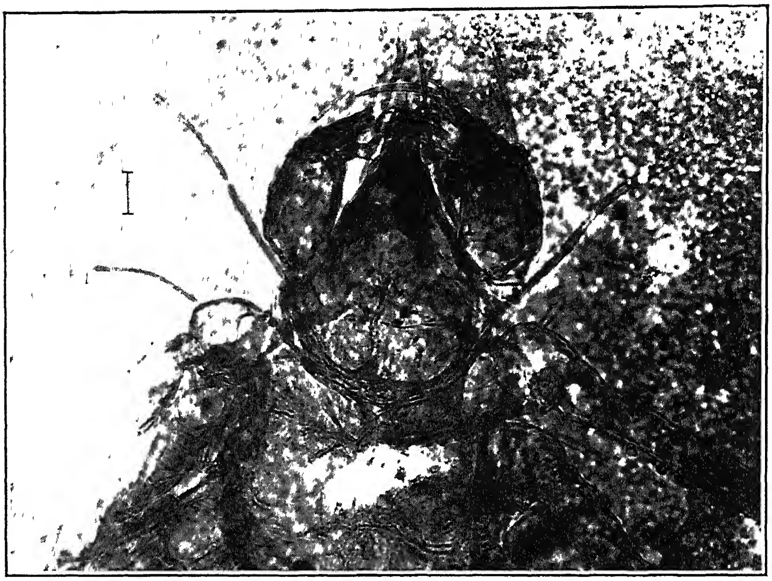
Streams brought to the lake not only fine mineral particles in suspension but also the elements of other minerals in solution. Those particles that rode in on the streams' turbulence found nothing buoyant in the quiet lake and hence settled placidly to the bottom. But the elements in solution were dispersed through the whole water body and, under the influence of the sun's warmth and the breathing of minute plants, combined with other elements to form tiny white flecks of mineral—particles of lime carbonate. These settled to the bottom as a gentle rain the year around, but most plentifully in the early summer, and formed a light-colored granular deposit that separated the dark organic layers from one another. Thus, because the dark organic layers were formed at a certain time each year and because the organic matter was then abundant enough to mask out the light-colored par-

ticles, each dark layer told off the passage of a year.

The ancient lake continued to serve as an annual calendar in this manner for thousands and thousands of years, interrupted only at long intervals by a fall of volcanic ash or by a storm of extraordinary vigor that stirred even the deep bottoms. The layered deposit was ultimately changed into rock, but the thin velvety dark bands still stand out sharply from the light-buff matrix. These layers are very thin—about 150 of them to the inch. This means that it required about 1,800 years for enough material to accumulate on the bottom of the ancient lake to make a slab of rock one foot thick. As might be expected, the varieties of rock consisting of the coarser mineral particles were built up somewhat more rapidly than this, and the finer-grained rocks, those consisting predominantly of organic substance, much more slowly. The measured rates of accumulation range from 250 to 8,200 years to the foot. By applying the rate at which each kind of sediment accumulated to the quantity of that kind of sediment throughout the body of material deposited in Lake Uinta it has been possible to estimate that the lake was in existence approximately 7,500,000 years. In this long period evolution had time to remold some of the more impressionable races of animals living in the neighborhood. For instance, ancestors of the horse family that lived at about the time Lake Uinta vanished were larger and had notably better grinding teeth than their forebears that lived just before the lake came into existence; moreover, in that interval evolution also altered somewhat the design of their toes.

In the record which the ancient lake kept year by year, we find the suggestion that the lake's volume and temperature varied in sympathy with the changing face of the sun—that is, with the number of sun-spots. Admittedly this correlation is no more than a suggestion, yet there is a fairly sound theoretical basis for believing it to be real. Foregoing all effort to explain the steps, we may present the argument in its briefest form somewhat as follows. Sun-spots are most numerous at intervals of about every 11 years, and these cycles signify changes in the amount of radiant energy that the sun emits. It has been observed that the levels of lakes which lose most of their water by evaporation and relatively little by overflow show a much closer relation to the number of sun-spots than to rainfall, in general, the fewer the sun-spots the lower the lake level. Lake Uinta at this stage had no outlet and lost much of its water by evaporation—therefore it must have had such a cyclic fluctuation of level. Next, in general the temperature of lake water rises as the lake goes down, and the higher temperature favors the growth of the minute surface-dwelling organisms and also the precipitation of particles of lime carbonate. This gives a further check on the ancient conditions, for in the deposits of Lake Uinta the layers of organic substance and lime carbonate differ in thickness from year to year and show maxima at intervals that average about 11 years. Similar cyclic variations have been observed in the thickness of annual layers formed in modern lakes. It is also a suggestive fact that the annual rings of trees that grew around Lake Uinta show even better the same 11-year cycle, just like the growth rings in modern trees.

Much longer cycles, whose average length was about 21,000 years, are also recorded in the deposits of Lake Uinta. By a somewhat more involved line of reasoning we are led to think that these observed variations in the lake deposits may be correlated with the resultant of two astronomic cycles—the change in eccentricity of the earth's orbit and the precession of the equinoxes. It remains to be seen whether these and other com-



AMERICA'S OLDEST "LOUSE"

BUT REALLY NOT A TRUE LOUSE, ONLY A RELATIVE—A PREDACEOUS MITE THAT LONG AGO FED UPON OTHERS OF HIS KIND NEAR LAKE UINTA. ITS TRUE SIZE IS SHOWN BY THE SMALL LINE AT THE LEFT WHICH IS ONE ONE-THOUSANDTH OF AN INCH LONG MAGNIFIED AS MUCH AS IS THE MITE. LIKE THE POLLEN GRAIN SHOWN IN THE SECOND PICTURE THE MITE IS EMBEDDED IN ROCK THAT HAS BEEN GROUND TO A THIN TRANSLUCENT SLICE

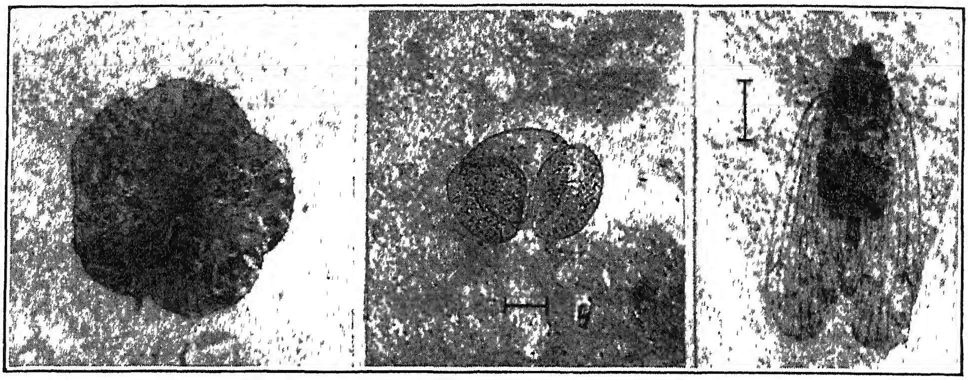
parable cyclic variations in the climate of the past can ever be used by meteorologists in their researches into secular changes of climate

III

Lake Uinta and the surrounding countryside did not always present a picture of smiling beauty, with forests and green meadows. Instead, during the later half of its existence death and starvation laid heavy hands upon the community. From time to time pallid blankets of volcanic ash descended upon it and snuffed out the life. Animals and plants alike were smothered, and the streams were clogged with the harsh mud. Gradually, as rains washed off the slopes, the forest renewed its growth and animals again sought its shelter. But it was to no purpose, for again and yet again at long intervals the volcanoes in the neighboring mountain chains belched forth devastating clouds of pumiceous ash.

As if these recurrent disasters were not enough, the rains came less frequently the very life-giving source of moisture began gradually but surely to dry up Under the pitiless summer sun the more lush plants withered and finally gave up, weary of waiting for the rain. Animals wandered away in search of water.

The lake, too, suffered. For a long time it overflowed only during the cooler rainy season, but as the years passed the thirsty air drew more and more greedily from its surface until finally even at the highest stage the water could not reach the outlet Thereafter Lake Uinta fluctuated greatly in size with the changing seasons and with every change in the weather, for a lake that has no outlet and



FLOWER, POLLEN GRAIN AND A FLY EMBEDDED IN ROCK

Left: THIS DELICATE CALYX OF AN ANCIENT FLOWER, PROBABLY RELATED TO OUR MORNING GLORY, GREW NEAR THE SHORE OF LAKE UINTA AND HAS BEEN PRESERVED IN STONE. *Center:* A PINE POLLEN GRAIN FROM THE ANCIENT LAKE UINTA. THIS SINGLE GRAIN IS GREATLY ENLARGED AND SHOWS THE TWO ROUGH-SURFACED, BULGING AIR SACS THAT ENABLED IT TO FLOAT THROUGH THE AIR FAR FROM THE PARENT TREE. THE POLLEN GRAIN IS SHOWN IN ITS MATRIX OF ROCK WHICH WAS ONCE BLACK MUD AT THE BOTTOM OF THE LAKE THIS PHOTOMICROGRAPH WAS TAKEN BY LIGHT TRANSMITTED THROUGH THE ROCK AFTER IT HAD BEEN GROUND SO THIN AS TO BE TRANSLUCENT. BELOW THE POLLEN GRAIN IS A BAR SCALE ONE ONE-THOUSANDTH OF AN INCH LONG ENLARGED THE SAME AMOUNT AS THE POLLEN. *Right.* A TINY FLY THAT SOME THIRTY MILLION YEARS AGO DANCED ABOVE A GLEAMING MUD FLAT ONLY TO HAVE ITS WINGS AND FEET CAUGHT FAST IN THE DRYING SURFACE FILM. ITS APPROXIMATE LENGTH IS SHOWN BY A LINE AT THE LEFT

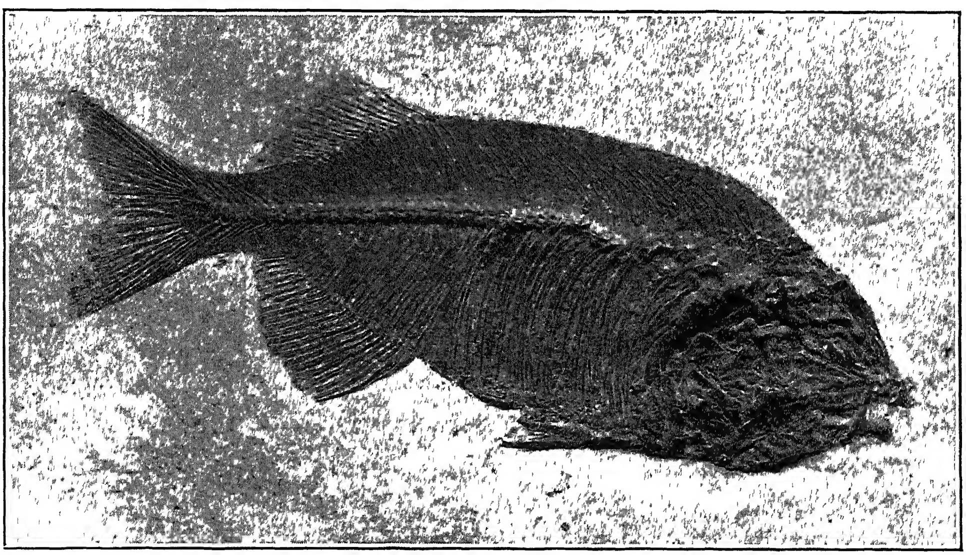
loses by evaporation as much as it receives is extremely responsive to slight variations in atmospheric conditions. As the water level varied it alternately flooded and left bare wide expanses of mud Upon these wet mud flats scores of fish were stranded and flopped until they stiffened in the sun. Insects, dazzled by the reflected glare from the wet mud, alighted only to have their wings and feet caught in the drying surface film When the water level rose again, perhaps only by reason of an onshore wind that pushed a thin sheet of water far up over the nearly level bottom, both fish and insects were sealed beneath a new layer of mud and so were preserved and made part of the enduring record.

As the lake retreated from its former shores it concentrated into smaller compass the community of living things that had formerly occupied a more spacious domain. The water was proportionately enriched in dissolved foodstuffs, and the density of the population increased manyfold. But conditions gradually became so congested that many forms were unable to survive. Their place, however, was immediately taken by a host of other organisms better fitted to endure the foul environment. Indeed, after thousands of years of slow dwindling Lake Uinta finally became, at its lowest ebb, a truly horrid thing—a great festering abscess breathing its stench into the shimmering summer heat. The water became bitter with salt, and the decaying organic material in the shallowest places seethed with fly maggots as they fed upon it. How abundant those maggots were is plainly told by the fact that layer after layer of them was buried, and to-day their overlapping flattened bodies make continuous paper-like layers in the thinly laminated rock that was once the lake-bottom mud.

This lowest stage in the history of Lake

Uinta indicates that the climate had changed from fairly humid to arid. The lake repeatedly deposited salt crystals along its shores and in the wet mud, but never were its waters so concentrated that continuous beds of salt were laid down. As shown by the annual layers the salt crystals formed only at intervals of about 50 years, which indicates that the water level even then rose and fell through a considerable range as the rates of supply and evaporation varied.

While Lake Uinta had no outlet and its level was prevailingly low the organisms lived in so great profusion that their remains accumulated on the bottom almost to the exclusion of anything else. But that this material endured long enough to be covered and so preserved means that it won a race with a host of bacteria and other scavenging hordes eager to destroy it In that race, however, it suffered partial decay; the individual organisms lost their identity and melted away into a jelly-like ooze, which finally became so charged with the toxic products of decay that it became intolerable even to bacteria. When decay finally ceased, the ooze became an excellent preservative, protecting from decay the delicate plants and animals that it accidentally entombed. As the organic ooze or gel was covered by successive layers and finally by thousands of feet of sediment it was compressed and gradually hardened into a dense substance resembling hard rubber. Geologists have examined this material under the microscope by grinding small pieces so thin as to be readily translucent. These thin plates of rock, suitably mounted on glass slides, show not only finely preserved microorganisms but in addition an odd assortment of wreckage, including the eyes of tiny insects, spatulate scales from mosquitoes' wings and an abundance of pollen grains. When this hardened organic substance is heated it yields a distillate of crude oil from which may be obtained gasoline, fuel oil and related products. Hence this substance derived from the former residents of the ancient



AN ANCIENT FISH

THAT ONCE SWAM IN THE WEEDY BAYS OF THE ANCIENT LAKE UINTA. THE PHOTOGRAPH IS REDUCED—THE FISH WAS MORE THAN A FOOT LONG

lake is known as "oil shale." So plentiful were the microorganisms and so long did Lake Uinta persist that its deposits now contain locked up the equivalent of more than 70 billion barrels of crude oil waiting to supply the nation's needs when the supply of petroleum from wells becomes inadequate.

Lake Uinta was blessed in its declining years by a return to conditions more nearly like those that attended its youth and middle life Refreshing rain heartened the forest to make another stand, and the gradually expanding lake finally purged itself by overflow. Plants of the kinds that fared badly during the protracted drought gradually spread down from the hills and resumed their former habitats But as the streams swelled and expanded the lake in this final stage, they brought with them an unwonted burden of waste from the land—waste that had accumulated during the dry epoch. Thus it came about that the lake was commonly turbid and could not provide, as formerly, the optimum environment for an immense population.

Moreover, the prime motivating force that brought Lake Uinta into existence and that made possible its long life was beginning to grow feeble. This force had been one of great magnitude, for it was this that had warped the crust of the earth gradually downward into the great basin-shaped depression which the lake occupied. And now that this force was weakening the streams were able to bring sand and silt into the lake a little more rapidly than the downwarping could make room for it. Hence the water became more and more shallow, and stream-laid deposits pushed ever farther and farther out into the basin until there remained only a vast alluvial plain dotted with swamps and small ponds. The streams that had so long paid tribute to Lake Uinta finally overwhelmed it and brought its rule to an end

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ARTIFICIAL PRODUCTION OF THE FABULOUS UNICORN

A MODERN INTERPRETATION OF AN ANCIENT MYTH

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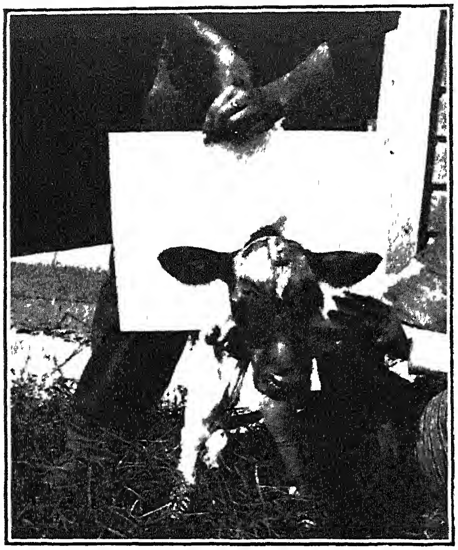
THE horn of the unicorn, once sought after by princes and kings for its magical powers as an antidote against the poisoned cup and so valued many times its weight in gold, has had an origin in actuality and mythology which remains, even to the present time, a mystery. Hope of discovering the unicorn's actual domain was ever present so long as there remained significant stretches of either land or sea as yet unexplored. But as all regions of the world gradually came under the eye of migrating and scrutinizing man, hope of finding the unicorn gradually faded until to-day our interest in its existence has come to lie only in the strangeness of the fantasy as an idealistic concoction of the imaginative impulses of man

The unicorn of mythology stands as the aristocrat of beasts, fearless, courageous, proud, strong and beautiful, gentle and the protector of other beasts. According to a typical description, he had the head and neck and the fine-boned, graceful legs of the horse; the beard and divided hoofs of Capridae; the tail of the oryx; and a single spike springing from the center of the forehead twisted in spirals, as is the tusk of the narwhal (*Monodon monoceros*). The horn is generally characterized as "de splendore mirifico" and was described by Ctesias, physician to the Court of Darius in Persia, as early as 398 B C. "The base of this horn, for some two hands'-breadth above the brow, is pure white; the upper part is sharp and of a vivid crimson; and the remainder, or middle portion, is black." Fresnel says of the horn that it "springs from between the eyes. For two-thirds of its length it is of an ashen grey-colour, like the rest of the animal, but the upper third is a vivid scarlet." With his horn he purifies the streams of poison so that all animals may drink in security.

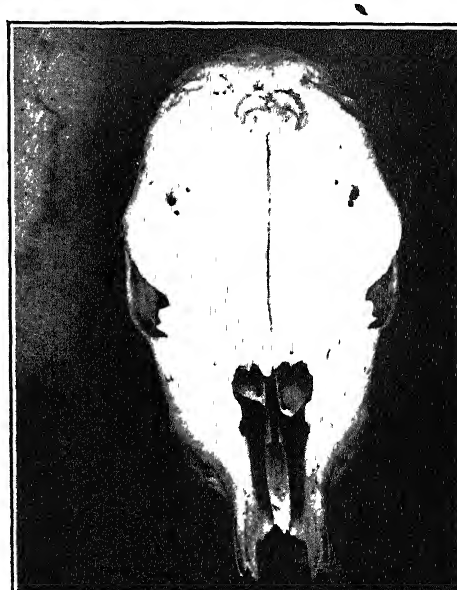
This strange one-horned creature, the history of whose imprints on the thought of man has been traced in so scholarly a manner by Odell Shepard in his "Lore of the Unicorn," back through Pliny, through Aelian, through Ctesias, beyond the Palace of Forty Pillars to legends possibly older than the Avesta and the sacred religious documents of Persia, is lost as the myth fades with man himself into the past. But elusive as he is, he provokes the statement of Shepard that he is "so credible, or rather so probable, in appearance as to make the hardiest doubter feel that if there is no such animal then an excellent opportunity was overlooked in the process of creation. He seems to fill a gap in nature."

Perhaps only a crude and literal-minded modern would lay hands on an object so endowed with sacred meanings as is the unicorn To attempt to produce artificially the object of such a glorious myth may seem tantamount to the ridiculous, even to the profane. But a method by which the unicorn can be made may account for the "authentic" observations and descriptions of unicorns that have been reported in every past century. It is possible that some of the descriptions in literature are truly authentic reports of living unicorns, unicorns who have been produced by actual manipulation



FOREHEAD OF NEWLY-MADE UNICORN.
THE TWO HORN BUDS HAVE BEEN TRANSPLANTED FROM THEIR ORIGINAL POSITIONS AT THE CORNERS OF THE SKULL TO THE NEW POSITION IN THE CENTER OF THE FOREHEAD BY MEANS OF PEDICLED FLAPS OF SKIN. THESE PEDICLED FLAPS ARE LEFT ATTACHED AT THE POLE IN ORDER TO ENSURE A SUPPLY OF PABULUM WHILE THE TRANSPLANTED HORN BUDS SECURE NEW VASCULAR CONNECTIONS, FUSE AND MAKE ATTACHMENT TO THE SKULL

That the unicorn can be produced artificially has been suggested a number of times in the past Le Vaillant, 1796, in his "Travels in Africa," describes a process of manipulating the horns of oxen. "As the horns of the young ox sprout they are trained over the forehead until the points meet. They are then manipulated so as to make them coalesce, and so shoot upwards from the middle of the forehead, like the horn of the fabled unicorn." Many centuries before Le Vaillant, Pliny had described in detail this method of twisting horns together. "And in very truth the hornes of these beasts (oxe) are of so pliable a substance and easie to be wrought, that as they grow upon their heads, even whilst the beasts are living, they may with boiling wax be bended and turned every way as a man will" Again in almost contemporary times the British Resident at the Court of Nepal is quoted by W S Berridge ("Marvels of the Animal World," 1921) as sending reports of unicorned sheep in Nepal with a description of the manner in which they may be produced. "By certain maltreatment ordinary two-horned sheep are converted into a one-horned variety. The process adopted is branding with a red-hot iron the male lambs when about two or three months old on their horns when they are beginning to sprout The wounds are treated with a mixture of oil and soot and when they heal, instead of growing at their usual places and spreading, come out as one from the middle of the skull" Shepard quotes another recent observer as writing (in 1924) that the "Dinkas,



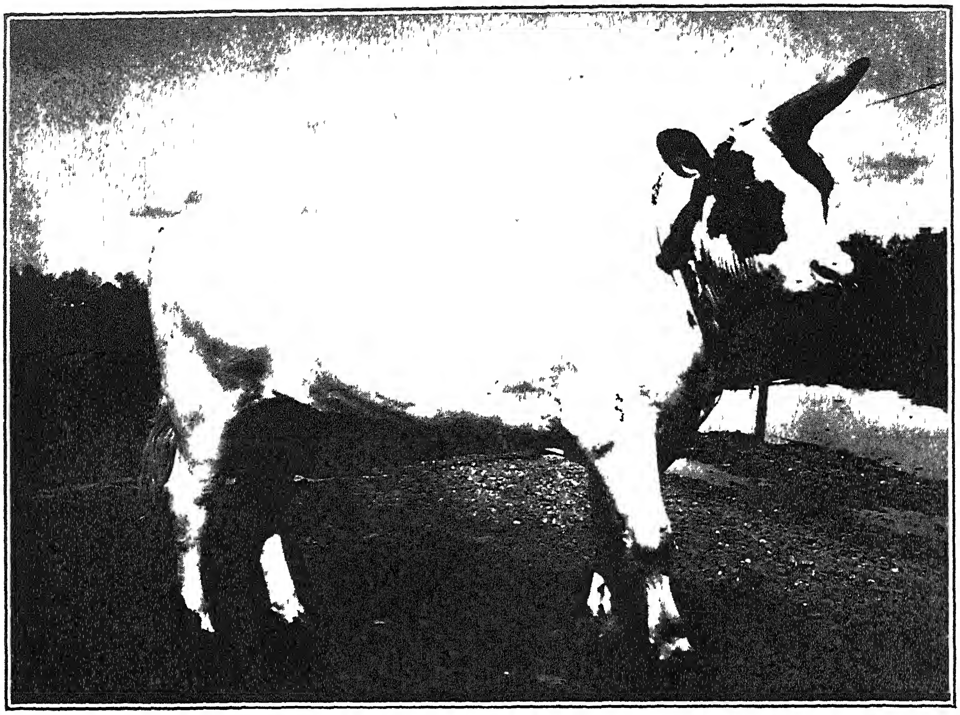
THE TWO HORN SPIKES
GREW FROM THE CENTER OF THE HEAD OF A POTENTIAL UNICORN 4 MONTHS OLD. ONE MAY OBSERVE THAT THE OS CORNUA HAVE FUSED TOGETHER. LATER THEY FORM ONE SOLID HORN SPIKE. CONTRARY TO THE SUPPOSITION OF CUVIER AND OTHER EARLY NATURALISTS, THE YOUNG HORN SPIKES HAVE FUSED TO THE SKULL ABOVE THE FRONTAL SUTURE.

who live just south of the White Nile, not only manipulate the horns of their cattle as the Kaffirs do but use this practice as a means of marking the leaders of their herds"

Scientific scrutiny, however, has tended to pick flaws in descriptions of this process. As Berridge goes on to say, "Notwithstanding the above explanation, the majority of naturalists are inclined to doubt whether a true understanding has even yet been arrived at concerning these sheep [of Nepal], for it has been pointed out that the mere fact of searing the budding horns would not result in those appendages sprouting out at the summit of the skull instead of towards the side, and moreover, if there is any secret attending their production it has been remarkably well kept from the ever-prying eyes of zoologists. It is true that the horns of a young animal might be induced to grow together by binding them up, but in that case we should expect the bony supports to be bent aside at their bases as a result of the unnatural strain put upon them, whereas on the contrary, those of the unicorn sheep arise in quite a straight manner from the skull" Shepard points to Cuvier (1827), among others, who "speaking as a scientist says that any horn growing single would be perfectly symmetrical, and that no such horn has ever been found. A cloven-hoofed ruminant with a single horn, moreover, would be impossible, in his opinion, because its frontal bone would be divided and no horn could grow above the division."

But despite the question marks raised by zoologists, Shepard, who is nothing if not impartial in his judgment of conflicting evidence, concludes. "It seems possible, therefore, that what I may call the unicorn idea, the notion that one-horned animals exist in Nature, arose from the custom of uniting the horns of various domestic animals by a process which is still in use but still mysterious to the civilized world. Here may be the explanation of the one-horned cows and bulls that Aelian says were to be found in Ethiopia and of the unicorned cattle reported by Pliny as living in the land of the Moors. The cows with single horns bending backward and a span long seen by Vartoman at Zeila in Ethiopia may have been of this sort. The one-horned ram's head sent to Pericles by his farm-hands may have been that of the leader of their flock, and so a perfect symbol of that leadership in Athens which according to Plutarch's interpretation, they wished to prophesy for their master. Finally, the mysterious one-horned ox mentioned three times over in the Talmud as Adam's sacrifice to Jehovah may have been the most precious thing that Adam possessed, the leader of his herd of cattle"

THE UNICORN AT 15 MONTHS OF AGE. THE TWO HORN SPIKES HAVE FUSED TOGETHER TO FORM ONE MASSIVE HORN SOLIDLY ATTACHED TO THE SKULL.



THE MATURE UNICORN AT 2 YEARS OF AGE.
THE SINGLE HORN CONTINUES THE GRACEFUL CURVE OF THE BACK. THE DARK TIP OF THE HORN MAY BE RECOGNIZED AS A SPOTTING FACTOR ASSOCIATED WITH THE DEEP REDDISH-BLACK COAT COLOR PATTERN OF THE ANIMAL.

As has happened before and may happen again, investigators have been too quick to condemn what has seemed to them mere credulity. Cuvier, like all his contemporaries, was mistaken in his idea of horn structure The writer has reported recently (*Journal of Experimental Zoology*, 69: 347–405, 1935) that the bony horn cores of ruminants (*Bos taurus* and *Capra domestica*) are not outgrowths of the skull (frontal) bones, as comparative anatomists have generally considered them to be, but are rather the products of separate ossification centers with their anlagen residing in tissues above the frontal bones, and that these anlagen or horn buds may be transplanted in whole or in part to other regions of the head where they take root and develop as true horns or parts of horns either solidly or loosely attached to the skull, according to the method of transplantation.

Since these horn-forming tissues have an integrity of their own and are self-governing (a quality not generally encountered in transplantable tissues and among the higher animals unique with horn tissues), the opportunity was available to study the ability of these tissues, when brought closely together, to fuse In March, 1933, an operation was performed on a day-old male Ayrshire calf The two horn buds were cut and pedicled so as to lie closely together over the frontal suture at the intersection of lines drawn from the occipital foramina and the original horn loci. The circular horn buds were trimmed flat at their point of contact so as to provide a larger fusion

surface. The transplanted tissues were also placed in direct contact with the frontal bones—the frontal periosteum having been removed in order to insure subsequent attachment of the developing os cornu (bony spike of the horn) to the frontal bones. It was expected that the two horns would fuse together into one large horn solidly attached to the skull and located between and somewhat above the eyes, as is the horn of the unicorn.

The experiment was successful. The animal, now two and a half years old, bears upon the forehead the stamp of the once fabulous unicorn. The two buds have coalesced and have formed one exceptionally large and long horn molded into the skull bones of the forehead for support. Cuvier's argument that the separation of the frontal bones at the point of origin of the horns precludes the existence of the unicorn is shown to be unfounded, since the horn spike grows not *from* the skull but *upon* the skull, first as an epiphysis, later to fuse to the frontal bones over the suture as a horn spike solidly attached to the skull. A single united sheath covers the horn spike. The horn curves slightly upward toward the tip and gracefully extends the curve of the back and neck when the animal stands at attention. Like that of the mythical unicorn described by Ctesias and Fresnel, the horn sheath is white or greyish-white at the base and is tipped with black. (Had the unicorn been a female, the horn would be tipped with red, since the color appears as a sex-limited factor in this particular breed. Both colors are mentioned in descriptions of the unicorn's horn. Light refracted from the glistening deep-red or black tip often produces a scarlet hue.) This Ayrshire bull, whose Scotch ancestors flourished under that Scotch king James I, who put the unicorn on Britain's coat of arms, is a true unicorn. True in spirit as in horn to his prototype, he is conscious of peculiar power. Although he is an animal with the hereditary potentiality for two horns, he recognizes the power of a single horn which he uses as a prow to pass under fences and barriers in his path, or as a forward thrusting bayonet in his attacks. And, to invert the beatitude, his ability to inherit the earth gives him the virtues of meekness. Consciousness of power makes him docile.

Even though the unicorn can be actually produced, one may still question any statement that the Kaffirs or the Dinkas or the men of ancient times knew how to produce unicorns by transplanting horn-forming tissues. But a statement made by Pliny in his "Naturalis Historial," Book XI, would lend credence to such a statement. In discussing the horns of oxen, Pliny says: "atque incisa nascentium in diversas partes torqueantur, ut singulis capitibus quaterna fiant." While this reference has to do with the artificial production not of unicorns but of multi-horned animals and was therefore very naturally overlooked by Shepard, nevertheless the words "incisa" (to cut) and "torqueantur" (to twist awry or to writhe) clearly denote the modern method of skin transplantation by means of pedicled flaps, *i.e.*, strips of skin so cut that they remain attached at one end for blood supply while the other end of the strip (containing, in this case, the horn bud) may be twisted or shifted to another part of the animal body as a transplantation. This reference indicates that the men of Roman times had the secret of horn bud transplantation. The same secret may have been shared by those Hebrew shepherds who, according to biblical references, made the unicorn the leader of their flocks.

According to our literature, an aristocratic nature is inherent in every unicorn. He is always the leader. Quite rightly so, and for reasons quite acceptable to behavioristic interpretation. Any animal fronted with a single horn would

learn the advantages of a single well-placed weapon and would, through experience, gain ascendance and leadership over the rest of the herd. To take a modern parallel, it is common knowledge among Argentine gauchos that the mulley animal is generally able to dominate the horned animal. The animal lacking horns usually has a well-developed frontal eminence which with the straight body weight behind it produces a more telling impact than does the side cut and slash of the horned animal. Should there be joined in one animal the mulley's potential impact with a powerfully blunt horn centrally posited, the animal would undoubtedly come to be invincible. Thus, in true modern fashion, we invert cause and effect. We can not say that the ancients made unicorns of the leaders of their herds, especially in view of the fact that such a transplantation as we have described must be effected shortly after birth when qualities of leadership are not yet discernible. But we say rather that the presence of a single horn upon the forehead of any single beast in the herd or flock gave it the incentive for leadership through a power which it learned only by experience.

The artificial production of the unicorn can serve only a very minor part in explaining a myth which has been so greatly elaborated. But such an experiment shows that if the unicorn's horn can be artificially produced by the transplantation of tissues and that if a single compound horn can arise from the forehead as a graceful and forceful weapon, then the secret may have been known to past ages—especially since an actual reference to horn tissue transplantation exists in Pliny. If even the extravagant color pattern of the horn, a white base tipped with red or black, is duplicated in the Ayrshire, then the same color scheme or one similarly extravagant could surely have been produced in ancient breeds. Finally, the experiment propitiates the modern desire to analyze behavior as the product of experience. It shows that possession of a powerful weapon alters the behavior of the animal selected to become a unicorn and indicates that the unicorn's dominant and aristocratic behavior can be brought out as a single behavior factor, unassociated with genetic origin. The dominance of a unicorned animal over the ordinary two-horned beasts of the herd is here offered as a striking instance of the dependence of behavior upon form.

In 1673 a Dr. Olfert Dapper described a unicorn observed wild in the Maine woods. "On the Canadian border there are sometimes seen animals resembling horses with cloven hoofs, rough manes, a long straight horn upon the forehead." In these same Maine woods may be seen to-day an authentic unicorn. The reader is invited to join the ranks of the many "credulous" men who have actually seen a unicorn with horn "white at the base and scarlet tipped, the leader of the herd, who can not be captured or taken alive."

SCIENCE AND THE ART OF CHEESEMAKING

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ONE of the finest examples of how an art may, by rule of thumb methods, develop a control of complicated biological forces is found in the practices of the cheese maker. If a large vat of milk could be divided among five cheese makers from five different nations, we could obtain five types of cheese differing radically in their appearance, physical properties and flavor.

If the cheese maker were English, he would probably make a firm-bodied, mild-flavored Cheddar; if he were from Holland he would make his part of the milk into Edam or perhaps Limburger with its high flavor and odor; an Italian would probably make a hard, dry Parmesan with small round holes, requiring two years to develop its sharp flavor; a cheese maker from Southern France would make his milk into Roquefort, a cheese with a piquant flavor and a white curd mottled with blue-green mold; and if the cheese maker came from Switzerland he would certainly convert his milk into a big Emmental or Sweitzer, puffed up with gas holes, and with a rubbery texture and a peculiar sweetish flavor.

To these characteristic cheeses could be added a long list of other cheeses, each with its own peculiar appearance and flavor. In each one the flavor is due to the growth of certain definite types of microorganisms occurring, for the most part, in the original milk. The development of the particular kind necessary to produce the flavor required for each cheese is secured by the methods of making and the curing or ripening process which follows. The cheese makers obtain this control by variation in the treatment of the curd in the vat, by varying the amount and method of salting, by the control of the temperature and humidity of the curing rooms, and to some extent by the addition of cultures of microorganisms.

These methods, even the use of cultures, were established long before Leeuwenhoek, with his crude microscope, saw for the first time the tiny organisms which became known to us as bacteria.

Before the action of these cheese organisms can be described, it will be necessary to discuss briefly the nature of the milk from which the cheese is made and the changes its constituents undergo in the making and ripening processes. Cow's milk contains about 12 per cent. of solids in solution or suspension in water. The milk sugar, the minor proteins and most of the minerals are in a true solution. About one third of the solids is fat in the form of small globules in an imperfect emulsion. The white appearance of milk is due to the casein, a complex protein maintained in a colloidal condition by various factors, among which are a combination with calcium. In other words, so long as it remains combined with calcium it exists in extremely fine particles evenly distributed throughout the fluid. When milk is acidified by the addition of an acid, the casein is freed from its combination and separates in flocks or lumps of curd. The same reaction occurs when certain types of bacteria, growing in the milk, ferment the milk sugar and produce sufficient lactic acid to precipitate the casein.

The casein may also be changed from its colloidal condition by the action of the enzyme rennin. These two reactions used separately or in combination are the basis for the manufacturing procedure

for nearly all the various types of cheese. The bacteria employed are usually the ordinary lactic streptococci of sour milk and the rennin, known commercially as rennet, is obtained by making an extract of the stomachs of young milk-fed calves.

The simplest form of cheese with which we are familiar, cottage cheese, is merely skimmed milk curdled, usually by bacterial fermentation alone but sometimes by the addition of a small amount of rennet. When the curd becomes sufficiently firm it is cut into small pieces which settle to the bottom of the vat, leaving the straw-colored fluid known as whey. This contains the unfermented milk sugar and other soluble constituents and is discarded or used to feed farm animals. The granular or flaky curd is salted and is ready for consumption without further preparation. In this simple cheese the only part played by bacteria is the preliminary fermentation of the milk which gives it its mild acid flavor.

In Neufchatel and Philadelphia Cream cheeses the bacterial action is very similar to that in cottage cheese, but another factor is introduced which materially alters the nature of the product. After the curd is separated from the whey it is subjected to pressure for several hours, which still further reduces the water content and thus restricts bacterial activity. The semi-hard cheeses, like Brie, Camembert, Roquefort, and Stilton, are pressed only enough to remove the excess water, but all the so-called hard cheeses are pressed until the curd is firmly matted together.

In Cheddar, named from the English town where it originated, there is a ripening process in which the flavor and physical properties of the cheese are materially changed. This cheese, which is the one most extensively made in this country, is started in much the same way as cottage cheese, except that it is made from whole milk and is always curdled with rennet. After the curd is cut up it is held in the warm whey with constant stirring and when the whey is withdrawn the curd is piled up on the bottom of the vat to continue the acid fermentation. When this reaches a certain point the matted curd is run through a mill which cuts it into small pieces. Salt is added and the curd is packed in hoops and held under pressure over night. The following day the pressed curd, now a firm homogeneous mass, is put away on shelves in a cool room to ripen. Much of the cheese is put on the market when only a few weeks old, but to get the real Cheddar flavor it is necessary to hold it several months. In this time a real digestion takes place and the curd, at first tough and rubbery, becomes soft and a characteristic flavor develops. The digestion is brought about, partly at least, by the enzymes in the milk or introduced with the rennet, but the peculiar flavor is the result of the slow growth of bacteria. It has not been definitely determined just which bacteria are responsible for the flavor of Cheddar cheese, but it is evident that the groups which ferment milk sugar to lactic acid are important factors. The entire process of making and curing is designed to encourage the growth of this type of bacteria.

In highly flavored cheeses of the Limburger type, a more rapid bacterial fermentation is induced by increasing the water content. In the milder flavored cheeses the ripening is in the nature of a digestion with a conversion of the insoluble casein into simpler water-soluble products, but in Limburger some of the products characteristic of putrefaction appear.

A quite different type of ripening takes place in some of the soft cheeses, of which Camembert is the best known example. The making of these cheeses begins with the usual rennet curdling and lactic fermentation, but they receive

no pressing except that the curd is drained in perforated metal hoops and is pressed into its final form by its own weight. These small cheeses, rather high in moisture, are salted by rubbing the salt into the surface of the cheese and are then placed on boards on the shelves of a cool, moist room. In a new factory it is necessary to inoculate the cheese with the essential mold, but after the factory has been in operation some time this mold infection takes place naturally. The mold that gives Camembert its flavor is a common variety, but is so characteristic of this cheese that it has been named *Penicillium camemberti*. It grows vigorously on the cheese, covering the entire surface with a thick white felt. Since molds are strictly aerobic the growth is confined to the surface, but the molds are active producers of a great variety of enzymes and these gradually penetrate the interior of the cheese. Their action is soon evident in the softening of the curd near the surface due to the digestion of the casein. This change proceeds inward until in a few weeks the entire cheese is semi-fluid and has the very characteristic Camembert flavor. This cheese ripens rapidly and is usually marketed when the softening has advanced only a short distance into the cheese.

Another type of mold-ripened cheese, in which the mold grows in the interior of the cheese, requires a longer and more complicated ripening. This type includes the English Stilton, the Italian Gorgonzola and the French Roquefort. This latter cheese is most exacting in the conditions required for its satisfactory ripening, and its development was brought about through a combination of natural conditions in Southern France. Roquefort is made from sheep's milk, not goat's milk as many suppose, and until a few years ago its manufacture was confined to the vicinity of the little town of Roquefort. In the limestone hills around this town are caves with openings at different elevations. The evaporation of water from the walls of the caves cools the air, causing rapid downward currents, until, at the lower levels, the air is cooled nearly to freezing and is saturated with moisture. Caverns have been cut into the side of the mountains intersecting the natural caves, making curing rooms through which the flow of the cold damp air is regulated to secure the required temperature and humidity. A special breed of sheep has been developed with exceptional milk production. The cheese is made in small factories, but is all brought to Roquefort to be cured. There is, as usual, a preliminary lactic fermentation, but bacterial growth in the cheese is restricted by the relatively heavy salting given the cheese in the first stages of ripening.

The Roquefort mold with which the cheese is inoculated is grown in the interior of loaves of bread held under suitable conditions so that the bread finally becomes a mass of mold in the spore stage. This is dried and ground to a powder and, as the curd is dipped into the hoops to drain, a little of the powdered mold is sprinkled over it.

Penicillium roqueforti is one of the common molds, but it has one distinguishing characteristic which adapts it to the task of ripening Roquefort cheese. Like all other molds it grows only where it can obtain air, but unlike most of them it can grow slowly when the supply of air is very limited and it is this fact that enables the cheese maker to restrict the molds in the interior of his cheese to this one species.

The close texture of the normal cheese effectively excludes air from the interior, but after the salt has been applied and the curd is sufficiently firm a large number of small holes are punched in the cheese with steel wires. These holes admit enough air to encourage the slow growth of the Roquefort mold, but not

enough to permit the development of foreign types. The atmospheric conditions essential to the proper ripening are very exacting. The temperature of the curing rooms must be not higher than 48° F. and the relative humidity must be near the saturation point. If these conditions are not constantly maintained the cheese becomes discolored and the flavor is abnormal. When all the conditions are right the Roquefort mold grows along the line of the holes, spreading into the curd and giving the cheese its mottled appearance. When the mold is sufficiently developed the cheese is wrapped in tinfoil and moved to a room held at about 40° F. This low temperature checks further growth of the mold but permits the continued action of the mold enzymes which develop the peculiar flavor characteristic of this cheese. The peppery flavor which distinguishes Roquefort from other cheese comes from the decomposition of one of the glycerides of which milk fat is composed. Sheep's milk has more of this particular glyceride than cow's milk, and for this reason sheep's milk is especially suited to the manufacture of Roquefort.

It is quite possible, however, to make Roquefort from the milk of goats, and through the efforts of the Bureau of Dairy Industry of the Department of Agriculture, Roquefort of excellent quality is made in this country from cow's milk and ripened in curing rooms in which the temperature and humidity are controlled artificially. This is only another illustration of the well-established fact that the production of a particular variety of cheese is not, as is frequently asserted, a matter of climatic conditions or peculiar herbage in the pastures but is dependent in a very large measure on the control of the growth of microorganisms. For a number of years a farmer on the Pacific Coast mountains has been making a good Roquefort from goat's milk which he ripens in a room built in a large spring of very cold water. The water not only flows under and around the room, but a flume carries it onto the flat roof so that it pours over the walls and in its fall turns a wheel connected with a fan to circulate the air inside.

Recently caves cut into the damp sandstone bluffs along the Mississippi at St. Paul have been utilized to cure Roquefort made from cow's milk, and now an abandoned shaft in a Pennsylvania coal mine is, after a coat of whitewash and the installation of partitions and dampers, making an excellent Roquefort curing room. The air forced through the wet shafts of the mine by the mine fan maintains this room at exactly 48° F. with a humidity near the saturation point.

If we go into the mountain valleys of Switzerland, we find a cheese with an even more complicated biological process and requiring more delicate control of conditions. A normal Swiss cheese weighs from 160 to 200 pounds and is made in a large copper kettle either suspended over a fire or provided with a steam jacket so that the milk may be warmed quickly and the temperature controlled throughout the making process.

To insure a good Swiss cheese it is necessary to bring about a succession of bacterial fermentations produced by different kinds of bacteria, each one taking up its work at the proper stage and supplementing what has been done by its predecessors.

The Swiss cheese makers had learned how to bring this about long before a bacteriological explanation was possible, and it is only in recent years that the bacteriological history has been worked out in detail. In this cheese the lactic streptococci, which are so important in most varieties, play only a minor rôle. Before the cheese is made a certain amount of growth of these bacteria should have taken place in the milk to

bring it to a certain degree of "ripeness," but when the rennet curd has been formed in the kettle and cut up into small pieces the temperature is maintained so high that the ordinary lactic streptococci can not grow. While in making Cheddar cheese the curd is allowed to mat on the bottom of the vat, the Swiss cheese curd is vigorously stirred until each particle becomes a firm granule not much larger than a grain of wheat. At just the right stage, which the cheese maker determines by the "feel" of the curd, the entire mass is scooped out of the kettle and put in a wooden hoop to press. In the meantime, the first of the essential bacteria have begun to develop. These are a group of lactic acid cocci which grow rapidly at the relatively high temperature of the whey in the kettle and of the curd in the press. These bacteria are actively engaged in fermenting the milk sugar to lactic acid, but the temperature of the curd falls in three or four hours below the limits of their activity.

There are only three or four varieties of bacteria working with the cheese maker, but no one could say how many there are which work against him. It is certain, however, that the one which gives him the most trouble is a group of gas-forming bacteria, always present in the milk and always ready when conditions come right to convert the milk sugar into acid and gas. The gas-formers are very detrimental to the cheese, and if they are not held in check may fill the curd so full of gas bubbles that it is like a loaf of fresh bread. The temperature in the kettle and in the curd for a few hours after it is dipped into the press is above their growth limit, but as the temperature slowly falls there is a critical time when they are able to again begin multiplication and the formation of gas.

The skilful cheese maker forestalls this contingency by making sure that the curd is well populated with another type of bacteria capable of combatting the gas formers. These are the lactic bacilli, which are even more active acid-formers than the lactic streptococci and continue their activity when the reaction of the curd has become so acid that other bacteria are inhibited. They also grow at higher temperatures than most of the gas formers and if they are in condition to become active promptly when the temperature falls to their growth limit they will be able to take up the work where the thermophilic cocci stopped and form acid enough to check the gas formers before they have done any harm. In 18 or 20 hours the lactose is nearly all converted to lactic acid and the curd is so acid that the danger from these gas formers is past.

The cheese is held a few days in a cool room, part of the time in a salt bath, and then is transferred to the warm room at 70 to 75° F., where a new group of bacteria takes up the work of the ripening or curing. The lactates formed from the lactose are fermented by these bacteria with the formation of propionic acid, a fermentation which gives Swiss cheese its peculiar sweetish flavor. Incidentally, carbon dioxide gas is produced. In Cheddar the open texture of the cheese allows the gases formed in the ripening to escape, but treatment of the curd in the making process gives the Swiss cheese a rubbery texture which holds the gas in bubbles expanding slowly to form the "eyes," the chief characteristic of Swiss cheese. If the fermentation has progressed properly the eyes are uniform in size and appearance, evenly distributed, and neither too large nor too small. If the eyes are right, it is almost certain that the flavor will be satisfactory. Consequently, Swiss cheeses are graded and the price determined by the appearance of the eyes.

When the eye formation has progressed to the proper stage, as indicated

by the swelling of the cheese, the cheeses are moved to a cool room for the completion of the ripening. The flavor is usually considered at its best when the cheese is five or six months old, but much of the domestic cheese is put on the market before this time has elapsed. The Swiss cheese maker must be very sure of the quality of his milk, not only in respect to the bacteria which it may contain, but also its physical properties when acted on by rennet and acid. Some milks form a tough curd that is not sufficiently elastic to permit the desired eye formation, while other milks curdle very slowly when the rennet is added, forming curd which never gets the rubbery texture required of a good cheese.

Milk which has too much fat gives the cheese a tendency to crack when it is expanded by the growth of the eyes, but if the cheese does not contain sufficient fat the curd is tough and dry. If the cheese maker is able to steer between these rocks he still has the undesirable bacteria to guard against.

The primitive cheese maker obtained his rennet extract by soaking a dried calf's stomach in whey. After standing over night in a warm place this whey contained not only the rennin extracted from the stomach, but a vigorous culture of the acid-forming bacteria from the previous day's cheese. This is a somewhat haphazard way of insuring the presence of the right kinds of bacteria, and in the up-to-date factories the dried rennets have been replaced by a commercial rennet extract, and pure cultures of bacteria from a laboratory take the place of the chance inoculation. Three cultures are now commonly used; the thermophilic streptococcus, which begins the acid fermentation in the curd; the lactobacillus, which carries it to completion; and the propionic bacteria, which are responsible for the flavor and at least part of the eye formation.

The latter culture grows slowly, but retains its vitality for a long time and can be furnished the cheese maker as bottled liquid cultures or in a dried preparation. It is only necessary to add a small amount to each kettle of milk.

The streptococci and the lactobacilli, on the other hand, must be grown in the factory so that they can be added to the milk at just the right stage of development. A bacterial culture, inoculated into fresh culture media, passes through three distinct stages each of which has its effect on the physiological properties of the cells making up the culture. There is at first the lag period in which the cells are increasing in size but not in number; then comes a period of rapid multiplication followed by a cessation of growth and a slow decline.

To insure the presence in the cheese of a large number of bacteria in condition to begin active growth when the temperature conditions permit, the cultures must be added to the cheese milk at just the right stage of growth. This requires accurate control of the temperature at which the cultures are grown and careful adjustment of the amount of inoculation and time of incubation.

The up-to-date cheese maker must provide himself with an incubator, sterilizer, flasks, thermometers and other equipment of a bacteriological laboratory and maintain his cultures in an active condition by daily transfers in sterile milk or whey.

It is not enough merely to add the cultures to the milk. The amount of culture must be carefully adjusted so that the acid development will, on the one hand, be fast enough to check the gas-forming bacteria and on the other not so rapid that the curd becomes dry and tough. The cheese maker can determine fairly well by various signs which he has learned to recognize if the acidity has developed properly, but in laboratory controlled manufacture the progress of the fermentation is measured by determining the hydrogen ion concentration

at intervals. If, three hours after the curd is put in the hoops to press, the acidity may be expressed by a pH of about 6.00, the thermophilic streptococci have begun the fermentation of the sugar. If five hours later the acidity has increased so that the pH is about 5.50, it may be assumed that the lactobacilli have taken up the work at the proper time. The next morning the pH should be between 5.00 and 5.20 and the milk sugar very nearly all fermented. The bacteriological balance in the cheese is so delicate that, if at this stage the cheese maker should change his mind and decide to make a Gruyere instead of a Swiss cheese, he could, by slightly altering the method of salting and curing room temperature, completely change the subsequent bacterial development. The gas formation is so suppressed that the eyes are small and round. The surface of the cheese is covered with a bacterial growth that causes a peculiar ripening proceeding from the surface inward and forming so much ammonia that the atmosphere of a Gruyere curing room is decidedly irritating to the eyes.

Any one who has attempted to follow the intricate balance which must be maintained to obtain a Swiss cheese of good quality, can not fail to have the greatest admiration for the men who learned to control this process without the least knowledge of the biological factors which were the basis of their methods.

A very large quantity of Swiss cheese is made in this country but almost entirely by Swiss people, many of them born in Switzerland and trained in the shadow of the Alps. They have retained their language and customs, and no convention of Swiss cheese makers is complete without its yodelers and wrestling and gymnastic contests.

Only a man of more than ordinary physique and constitution can withstand the hard work and long hours required in the operation of a Swiss cheese factory. His work begins in the early morning hours and, if the usual custom of making cheese from the evening milk is followed, it will extend well into the night. Between the actual making periods there are long rows of 175-pound cheeses to be taken from shelves, turned over and put back. It is related that one cheese maker, going through this routine, still had an unoccupied hour or two in the middle of the day, some of which he spent in working with a 50-pound dumb bell "to keep himself in good condition."

Swiss cheese making is scattered through several states, but by far the greater part is made in two restricted sections. One of these is in Ohio, but in southern Wisconsin there is a much larger district, with many well-constructed factories, some of them larger than any in Switzerland. Much of the cheese made in these factories is of excellent quality, but in general it suffers by comparison with the imported cheese because, while all grades made by the American factories go onto the market, Switzerland sends only carefully selected cheese to this country. It also suffers from the recently developed practice of grinding the poorer grades of cheese, melting the mixture and running it into molds to form a convenient package for marketing. Restaurant attendants have acquired the habit of referring to this product, which has lost the characteristics of the original cheese, as "domestic," while cheese with eyes is called "imported."

THE MALTHUSIAN PRINCIPLE IN NATURE

By W. L. McATEE

THE BIOLOGICAL SURVEY, U. S. DEPARTMENT OF AGRICULTURE

Introduction

The essay on the "Principle of Population" by T. R. Malthus ran through six editions (1798–1826) during the author's lifetime. In the first edition he "put forward the view that population, when unchecked, increases in a geometrical ratio, while subsistence increases in only an arithmetical ratio, and Malthus asserts as a fact that population always increases up to the limits of the means of subsistence."[1] In the second edition, "while maintaining his 'principle' of population—the universal tendency of population to outrun the means of subsistence—he allowed the question of the mathematical ratios to fall rather into the background."[2]

The Malthusian principle appears therefore to be an alleged "universal tendency of population to outrun the means of subsistence." It was used as a basis for arguments as to a struggle for existence resulting in natural selection and survival of the fittest by Darwin, who like various other authors did not sufficiently appreciate the vast difference between a theoretical potentiality and the actual realization thereof. As a matter of fact, it is seldom even in the very unnatural case of mankind, and rarer still in nature, that populations actually outrun the means of subsistence.

Geometric Increase

Referring to the human race, Malthus said, "population, when unchecked, goes on doubling itself every twenty-five years, or increases in a geometrical ratio," but "the means of subsistence under circumstances the most favorable to human industry, could not possibly be made to increase faster than in an arithmetical ratio."[3] This conclusion seems to have been reached by Malthus on the grounds of space for crops being limited, for he says: "Man is necessarily confined in room. When acre has been added to acre till all the fertile land is occupied, the yearly increase of food must depend upon the melioration of the land already in possession."[4] As much weight should be attached to the thought in the first, as to that in the second, of the sentences quoted. Space for mankind itself is limited and the human population can not increase indefinitely, because density becomes a factor in checking population growth, a point that will be more fully discussed later.

Modern studies of population growth have shown that it does not continue at a geometric rate (Pearl, Yule), but in each period of approximately uniform conditions, invariably levels off so that there comes to be no increase at all. In the words of Yule, who characterizes Malthusian speculations as nightmares, "growth does not follow the geometric law, but . . . the percentage rate of increase tends steadily to fall as numbers enlarge."[5] Since this development is at present taking place in our own and other countries where there is an excess of food, it is evidently not the result of

[1] Claude W. Guillebaud, Encyclopedia Britannica, 14th Ed., 14, p. 744, 1929.

[2] *Ibid.*, p. 745.

[3] T. R. Malthus, "An Essay on the Principle of Population, or, A View of its Past and Present Effects on Human Happiness; with an Inquiry into our Prospects Respecting the Future Removal or Mitigation of the Evils Which it Occasions," Fifth Ed., Vol. 1, pp. 9 and 14, 1817.

[4] *Ibid.*, p. 9.

[5] G. Udny Yule, *Jour. Roy. Statistical Soc.*, 88, p. 22, January, 1925.

a shortage in subsistence. The occurrence, moreover, negatives another of Malthus's cardinal propositions, namely, that "population always increases where the means of subsistence increase."[6]

That increase in food may have the same sort of ratio as that of population is shown by the fact that it has more than kept pace in the century since Malthus's time, during most of which a very rapid growth in population has occurred. As to the reason, the Secretary of Agriculture of the United States has recently said, "When it is possible for the farmers of a nation to increase production 50 per cent. while crop acreage is increasing only 25 per cent. we know that science has been at work. That is exactly what has happened in the United States in the past 30 years."[7] Referring to a definite part of this period, Dr. O. E. Baker says, "Between 1921 and 1926 agricultural production increased about 27 per cent. whereas population increased 9 per cent."[8]

The assumption that subsistence factors dominate population growth appears antiquated anyway in these days, when, although populations generally seem coming to a standstill, we are at the same time seeking agreement by international conferences to decrease food production, and nations are warning, forcing or even paying farmers to reduce crop acreages.

From a theoretical point of view, moreover, Malthus's assertion that population increases in a geometrical, food in only an arithmetical, ratio is unsatisfactory, as all man's food consists of organisms, every one of which has the same potentiality for geometrical increase as himself and most of them at a much higher rate. The extent to which the respective tendencies have been permitted realization is the effective factor. No domestic animal, for instance, is permitted to breed unrestrictedly. Man regulates such increase, and in some fashion he has always regulated his own increase. The problem of the growth of human population is an artificial rather than a natural one and even if the Malthusian principles held good for it, there would be no warrant for extending them to populations of organisms in nature, uncontrolled and unaffected by man.

Malthus stated his principle in a general form to the effect that there is a "constant tendency in all animated life to increase beyond the nourishment prepared for it,"[9] and he elaborated upon this idea as follows:

> Through the animal and vegetable kingdoms Nature has scattered the seeds of life abroad with the most profuse and liberal hand; but has been comparatively sparing in the room and nourishment necessary to rear them. The germs of existence contained in this earth, if they could freely develop themselves, would fill millions of worlds in the course of a few thousand years. Necessity, that imperious, all-pervading law of nature, restrains them within the prescribed bounds. The race of plants and the race of animals shrink under this great restrictive law; and man can not by any efforts of reason escape from it. . . .
>
> In plants and irrational animals, the view of the subject is simple. They are all impelled by a powerful instinct to the increase of their species; and this instinct is interrupted by no doubts about providing for their offspring. Wherever, therefore, there is liberty, the power of increase is exerted; and the superabundant effects are repressed afterwards by want of room and nourishment.[10]

What the Malthusian argument chiefly neglects is that "nourishment" in almost all cases is other organisms, each having the same sort of capacity for increase as the nourished. Consumer and producer are on the same, not on different, bases. Self-limiting factors also are not given proper weight.

[6] *Loc. cit.*, p. 34.

[7] H. A. Wallace, *U. S. Dept. Agr. Official Record*, 12: 19, p. 73, May 13, 1933.

[8] O. E. Baker, *U. S. Dept. Agr., Extension Circ.* 168 (mimeographed), p. 12, July, 1931.

[9] *Loc. cit.*, pp. 2–3.

[10] *Ibid.*, pp. 3–4.

Subsistence Effects

That "Population is necessarily limited by the means of subsistence"[11] is one of the chief Malthusian pronouncements. Just what the author intended to convey by the expression "means of subsistence" is not entirely clear, but if it be not taken as a synonym of food, the formula quoted becomes a pointless truism, "Population is necessarily limited by all things essential to it." If, as ordinarily done, we take the statement to mean that population is limited by the food supply, it is evident at once that an alternative mode of expression would be more truthful, namely, that population in some cases may be, or in the last extremity, must be, limited by food supply. While the quantity of food available undeniably sets an ultimate limit to increase in population, to assume that it is a factor constantly functioning in the regulation of populations is quite another matter.

The lavishness of nature gives us opportunities of observing in many cases that means of subsistence is not the factor limiting populations. Provision for reproduction of organisms characteristically is on a profuse scale. In the plant kingdom flowers as a rule are superabundant; unconsumed millions of them wither away, and their pollen, a nutritious food, is largely wasted, some of it in showers that color the landscape. There are some flower-eating creatures, and fairly numerous pollen and nectar feeders, but their populations would be much greater were the food supply the effective limiting factor upon them.

A similar situation prevails with respect to the eggs of some animals, those of pelagic breeding fishes, for instance, which are shed in countless millions and often cast upon shore in windrows where the great bulk of them disintegrate uneaten. The supply would set no humble limit upon the numbers of egg-eaters, yet the latter are limited after the fashion of organisms in general.

Leaves are pasturage for an immense number of organisms; nevertheless, the rule is for the trees to retain their foliage essentially unimpaired until it has fulfilled its function and falls, another increment to the forest duff in which form, furthermore, it is years in being utilized for nourishment, either by animals or plants. The prevailing rule—luxuriant greenery all about us—certainly indicates that it is not the supply of foliage that sets the limits for leaf-feeding organisms.

The means of subsistence of some organisms may be compared with an ever-bubbling spring, the flow of which is never consumed. Such a food is plant sap; it is never exhausted except extremely locally, yet the sap-feeders (most of the great order Rhynchota, for instance) maintain their populations evidently in accordance with the same principles that affect organisms utilizing nourishment apparently much more limited in abundance.

Comparable instances are those of larvae, such as tent caterpillars, which feed on newly expanding leaves. Often they seem to gnaw these down as fast as they grow, but as soon as the caterpillars complete their growth, out spring the leaves and clothe the tree with its normal foliage. In this case again subsistence evidently has not limited population.

Plant galls to which nourishment keeps circulating so long as their inhabitants are developing constitute a similar example. Some insects and other organisms are actually domiciled in a mass of their food, which in many cases is almost infinitely beyond their capacity to consume. The wood-boring larvae (Cerambycidae, Cossidae, Sesiidae, etc.) are excellent illustrations. The Prionines, Xylotrechines, Xylophagids, Clusiids, etc., have a similar relation to fallen

[11] *Ibid.*, p. 33.

trees, and generations of adults emerge year after year from the same log—from an enormous food mass, the presence of which evidently does not cause their populations to increase up to the subsistence limit.

Among organisms dwelling within their food, a great variety of internal parasites must not be forgotten. Though they live in the midst of plenty, they maintain, as a rule, average numbers, but assuredly not those which would be possible were available subsistence the controlling limitation upon their populations.

These instances may be considered as meager or atypical or even as capriciously selected. Such objections need not be replied to in detail, however, for the naturalist observes, in almost any direction he may turn, an apparent abundance rather than a scarcity of food supplies. The writer long ago showed that invertebrates and seeds could have such numbers even in winter as 1,216,880 animals and 2,107,810 fruits and seeds per acre, respectively, on the forest floor, and 13,654,710 animals, and 33,822,745 fruits and seeds per acre, respectively, in fields near Washington, D. C.[12] The average population of birds in this region is not more than from 2 to 3 per acre, a number that evidently is not fixed by the food supply. A similar case is presented in data relative to Oneida Lake, New York. F. C. Baker[13] estimates the number of herbivorous animals of the lake at 7,743 millions of individuals, and the carnivores at 23 millions. The latter population is only about three tenths of one per cent. as numerous as the former and its food supply therefore is enormously superabundant.

The theme could be elaborated at length, but that seems unnecessary. If populations were in reality limited as a rule by the means of subsistence, we would see on all sides starvation of populations and devastation of environments. The fact is we rarely see either. This statement is made with full consciousness of occasional local exhausting of food supplies by rabbits, hares and other animals.

P. P. Calvert noted in 1900 that:

> In spite of the continuous need of food by all animals . . . it is extremely difficult to point out cases where famine alone operates, under natural conditions, to increase the severity of the struggle for existence.[14]

In a translation dated 1904, August Weismann is recorded as saying that even "a low rate of multiplication is not in itself sufficient to prevent the excessive increase of any species, nor is the quantity of the relevant food-supply. Whether this be very large or very small, we see that in reality it is never entirely used up, that, as a matter of fact, a much greater quantity is always left over than has been consumed. If increase depended only on food-supply, there would, for instance, be food enough in their tropical home for many thousand times more elephants than actually occur; and among ourselves the cockchafers might appear in much greater numbers than they do even in the worst cockchafer year, for all the leaves of all the trees are never eaten up; a great many leaves and a great many trees are left untouched even in the years when the voracious insects are the most numerous. Nor do the rose-aphides, notwithstanding their enormously rapid multiplication, ever destroy all the young shoots of a rose-bush, or all the rose-bushes of a garden, or of the whole area in which roses grow."[15]

[12] W. L. McAtee, *Science*, 26: 666, 447–449. October 4, 1907.

[13] F. C. Baker, N. Y. *State Coll. Forestry. Circ.* 21, p. 30, August, 1918.

[14] P. P. Calvert, *The Veterinarian*, 73: 875, p. 594, November, 1900.

[15] August Weismann, "The Evolution Theory." Translated with the author's cooperation by J. Arthur Thomson and Margaret R. Thomson. Vol. I, p. 45, 1904.

Two years later Frederic Merrifield, in the president's address before the Entomological Society of London, said:

On the whole I think it would be difficult to show that any species of vegetable-feeding insect was ever wiped out or turned from a common kind to a rare one as a consequence merely of its food plant having been all—or nearly all—eaten down by itself or its congeners; so that whatever may be the cause of the remarkable numerical constancy we find in individuals of different species, this persistence can not be sufficiently accounted for by the relation between the food supply and its insect consumers.[16]

W. R. Thompson, more recently, has written that "any biologist who has observed the work of plant-feeding species in Nature will admit that obvious signs of severe injury are uncommon, while the total destruction of plants is extremely rare."[17]

In 1933 A. J. Nicholson summed the matter up in a way that naturalists must regard as fair, when he said, "It is generally recognized that in nature few animals die as a direct result of starvation."[18]

We must therefore conclude that the Malthusian principles, "population is necessarily limited by the means of subsistence" and "population always increases where the means of subsistence increase," do not normally function in nature.

Space Effects

Malthus would have been better advised had he insisted more on the element of room which he mentions both in connection with man and with lower organisms, but he chose to emphasize subsistence.

[16] Frederic Merrifield, The President's Address, *Proc. Ent. Soc. Lond.*, 1906, pp. cxix–cxxx (publ. with *Trans. Ent. Soc. London* for 1906), 1906–1907.

[17] W. R. Thompson, *Ann. Applied Biol.*, 17: 2, p. 315, May, 1930.

[18] A. J. Nicholson, *Jour. Animal Ecol.*, 2: 1, p. 166, May, 1933.

To introduce the evidence as to space effects we quote from Dr. Raymond Pearl:

It has long been known that the degree of crowding of organisms in a given space, or density of the population, has an influence upon various vital processes of the individuals composing the population. In the matter of growth of the individual animal Semper[19] long ago showed that volume of water apart from food and other conditions has an influence upon the rate. This subject has again been studied recently by Bilski.[20] Farr[21] maintained that there is in human populations under certain conditions a definite relation between density of population and the death rate. This old work of Farr's has recently been taken up again and confirmed by Brownlee[22] for certain portions of the population of England and Wales.[23]

Dr. Pearl's own experimental work was with the pomace fly (Drosophila) and in describing the results where the same number of flies were used as foundation stock in containers of different capacity, he says:

The maximum population is nearly five times as large, instead of twice, in the pint bottle as it is in the half-pint . . . while (the pint bottle) has a little more than twice as much free air space as the former, it has nothing approaching five times as much. If the surface area of the food, namely the area on which the adult flies can find yeast to eat, be considered . . . the case is obviously worse. The ratio of the larger to the smaller universe is not even so great as two.[24]

In other words, the growth of population was proportional to the volume of the container, not to that of the food.

[19] K. Semper, "The Natural Conditions of Existence as they Affect Animal Life," Fourth Ed. 1890.

[20] F. Bilski, *Pfluger's Arch. f. d. Gesamte Physiologie des Menschen u. d. Tiere,* 188: 4–6, 254–272, June, 1921.

[21] William Farr, Fifth Ann. Rep. Reg.-Gen. of Births, Deaths, and Marriages in England (2nd ed.), pp. 406–435, 1843; Suppl. 35th Ann. Rep. Reg.-Gen. of Births, Deaths, and Marriages in England (2nd ed.), XXIII–XXV, 1875.

[22] J. Brownlee, *Jour. Hyg.*, 15: 11–35, 1915; *Jour. Roy. Stat. Soc.*, 82: 1, 34–65, January, 1915; *ibid.*, 83: 2, 280–283, March, 1920.

[23] Raymond Pearl, "The Biology of Population Growth," p. 131, 1925.

[24] *Ibid.*, pp. 41–42.

In experiments with varying numbers of foundation stock in identical environments, he found that the production of imagos per mated female per day varied from 21.4 in bottles containing only one pair of the flies to 0 33 in those containing 50 pairs. He notes accordingly that, "there is a profound and regular change in the rate of reproduction of *Drosophila,* under the conditions of these experiments, with increasing density of population. The rate of reproduction per mated female declines as density of population increases, at first extremely rapidly, and then more and more slowly at higher densities."[25]

Generalizing the data available to him, Dr. Pearl concludes,

> that rate of reproduction or fertility is negatively correlated with density of population, in (a) experimental populations of flies, (b) experimental populations of hens, and (c) urban populations of human beings. This array of evidence indicates that in the direct and indirect biological effects of density of population upon reproduction exists one *vera causa* for the damping off of the growth of population as the upper limit of the logistic curve is approached.[26]

Another investigator, Morris H. Harnly, who also used Drosophila as a subject, sums up his findings in these words:

> Increase in the food volume (depth) with a constant area (24 sq. cm.) followed the law of diminishing returns—. . . until the optimum was reached (at 22 to 26 mm). Beyond that point additional food had no effect upon the total population supportable on a given area.[27]

The effects of crowding on reproductive rate have been noted also by various other authors. R. E. Lloyd, for instance, wrote in 1912:

> The fertility of captive animals often depends on space. Wild rats will seldom produce young when confined in small cages, but breed readily enough in a large enclosure. A pair of pigeons will produce no young in a small cage. The same pair, however, if removed to a large cage will breed, but the group of their descendants will cease to expand as soon as the cage becomes crowded, the numerical size of the group depending on the capacity of the enclosure.[28]

"In the case of plants" also, Yule notes that "there is a marked effect of density. Wheat and barley plants planted at close spacing do not merely show a reduction in yield of grain which might be attributed to starvation; the actual number of ovules formed on the first tiller is reduced, an effect which can be seen within the first month of the life of the plant."[29]

Oscar W. Richards states regarding experiments he conducted with yeast that while definite cycles of growth were demonstrated "the food supply was not a limiting factor."[30]

Referring to his own experiments on yeast and those of Terao on a water flea G. F. Gause says, "In these experiments there was one point in common . . . the equilibrium was not due to any deficiency of food" . . . and of further experiments of his own on *Drosophila,* "the sharp decrease of the density of saturating population at 30° temperature was not connected with any lack of food."[31]

In 1927 Everett Clark Myers reviewed experimental work on the effects of density upon protozoan populations and reported on extensive experiments of his own with *Paramecium caudatum.* The conclusions pertinent to the present discussion are as follows:

> Decreasing the volume of fluid . . . decreases the total population produced. The number present at the maximum is nearly proportional to the volume of the fluid employed. . . . As the density of population in a given volume of culture fluid increases, the rate of reproduction

[25] *Ibid.,* p. 136.

[26] *Ibid.,* p. 209.

[27] Morris H. Harnly, *Jour. Exp. Zool.,* 53: 2, p. 167, May, 1929.

[28] R. E. Lloyd, "The Growth of Groups in the Animal Kingdom," p. 30, 1912.

[29] *Loc. cit.,* pp. 34, 35.

[30] Oscar W. Richards, *Ann. Bot.,* 42: 165, p. 280, January, 1928.

[31] G. F. Gause, *Quart. Rev. Biol.,* 7: 1, p. 44, March, 1932.

falls off, finally ceasing. . . . In all cases the greater the number of individuals per volume, the less the reproductive power.[32]

Royal N. Chapman in breeding flour beetles (*Tribolium confusum*) found that the population increased up to a certain point, when the immature stages were eaten by the adults to an extent which held the numbers about constant. He also found that "the increase of a population is proportional to the total size of the environment."[33]

Writing of another grain-eating insect with which he experimented, D. Stewart Maclagan wrote in 1932:

Perhaps the most significant fact resulting from this analysis of the "space factor" is that the female *Calandra* will not lay the maximum number of eggs produced under the conditions of these experiments until the number of grains available are at least eight times that actually utilized. This does not occur until there are 400 grains to every female weevil, when the number of males and females in the population are equal. Even at the "optimum" in regard to space utilization for purposes of oviposition, nothing would induce the female weevil to utilize more than approximately 50 per cent. of the total available number of grains.[34]

Summarizing the findings of himself and others, Maclagan says: "Analysis of existing data combined with laboratory experimentation upon different insects, demonstrate the great definity of operation of the 'space factor,' also, the existence of an 'optimum' density for rate of reproduction,"[35] and concludes: "It would appear . . . that natural populations automatically check their own increase by virtue of this density effect, and that the organism itself imposes the ultimate limit to its own abundance when all other factors (biotic and physical) normally inhibiting population increase, have failed."[36]

It is fully evident that there is a space effect of importance in controlling certain plant and invertebrate populations. The phenomenon in the case of vertebrates has been the subject of ordinary observation by generations of naturalists, and has more recently been cast in the form of a territorial hypothesis. It has been most accurately observed, perhaps, in the case of game birds, and Leopold in his book on Game Management writes, "it may be said with reasonable assurance that within the main range of the bobwhite, a density limit of approximately one bird per acre exists and probably always has existed."[37] Moreover, the density of population apparently can not be increased by addition of species of similar environmental requirements, and upon this point Leopold concludes "that mixed stands are to a large degree subject to the same combined saturation point as would hold for pure stands of the constituent species."[38]

In attempting to explain the situation, Leopold uses language very reminiscent of that of Maclagan on insects.

If external or environmental forces alone determined maximum density, the maxima occurring in a large number of samples in one state . . . might be expected to run much higher or lower than in another. The fact that they do *not run* higher or lower in bobwhite on its main range is evidence that some *internal* force or property, which is not subject to large variation as between regions, is also operative, and sets the upper limits beyond which wild populations do not increase.[39]

In extended studies of the house wren, Kendeigh found that "the number of broods per female per season tends to

[32] Everett Clark Myers, *Jour. Exp. Biol.*, 49: 1, pp. 40, 41, 42, October, 1925.

[33] Royal N. Chapman, *Ecology*, 9: 2, p. 120, April, 1928.

[34] D. Stewart Maclagan, *Proc. Roy. Soc.* (*Lond.*), Ser. B, III (B773), p. 445, October, 1932.

[35] *Ibid.*, p. 454.

[36] *Ibid.*, p. 452.

[37] Aldo Leopold, "Game Management," pp. 52–53, 1933.

[38] *Ibid.*, p. 84.

[39] *Ibid.*, p. 54.

vary inversely with the total population."[40] On a certain tract in Ohio, he found that when the number of nests was 7 the broods per female was 1.8; when the number of nests was 14 the broods fell to 1.2 per female.

As a result of study of the great crested grebe in England, Venables and Lack conclude that territorial behavior in that species is not correlated with food supply, and cite other statements of the same principle which they deem general.[41]

A specific illustration of the principle may be cited from Harrisson and Buchan's report on the St. Kilda wren.[42] They state that:

> In one pair especially studied the territory was found to be composed of a number of sub-territories, small areas in which food was taken. These food territories constituted only 2.6 per cent. of the whole territory, and 85 per cent. of the food of the young was obtained in 1 per cent. of the whole.

Despite clear evidence to the contrary in some of the instances, certain laboratory workers have been inclined to consider the "space effect" at bottom a "subsistence effect." While this impression may have been favored by the results in some cases of artificial environments, the fact that "space effects" are known also in a state of nature where food normally is in excess points to the conclusion that "space effects" are a real entity, the course of which may sometimes seem to parallel "subsistence effects," but which is quite independent and may produce results in no way correlated with subsistence. This independence is further shown by the unfavorable results from undercrowding. Allee summarizes knowledge on this point as follows:

> It is easy to demonstrate that overcrowding lessens the rate of growth of organisms. More recently evidence has been accumulating that undercrowding frequently has the same effect. Evidence is presented on this point in such widely different animals as mealworms, fishes, and mice. Similarly, with population growth the harmful effects of undercrowding have recently been found for protozoans, crustaceans, and beetles, as well as the ill effects of overcrowding.[43]

POPULATIONS TEND TO BE SELF-LIMITED

In introducing this subject we take advantage of remarks made by experimenters with the flour beetle, one of the organisms cited in the preceding section as manifesting the "space effect," at least in microcosms.

Chapman and Whang in a paper from which convenient references to nine other articles on the general subject may be obtained, state that "population systems of flour beetles produce a resistance to their own potential rate of increase."[44]

T. G. Holdaway, who worked with the same insect, comments on self-limitation of its populations, and extends the principle to natural populations. He says, in part:

> Actually the theoretical geometric growth of the population does not take place. If it did the population would increase so rapidly and reach so high a concentration in a very short time that no food would remain and the population would perish . . . in nature the maximum rate of increase does not continue beyond a short period of time. There is generally some provision whereby the numbers are kept down and a more optimum concentration maintained, so that the food supply does not constitute a limit to the survival of the species . . . the important point is that self-limitation is possible and does occur.[45]

The provisions for keeping numbers down, the actual means of self-limitation of populations, are forces, the working of which every naturalist has observed,

[40] S. Charles Kendeigh, *Ecological Monographs* 4, p. 309, July, 1934.

[41] L. S. V. Venables and David Lack, *British Birds,* 28: 7, p. 191, 198, December, 1934.

[42] T. H. Harrisson and John N. S. Buchan, *Jour. An. Ecol.,* 3: 2, p. 144, November, 1934.

[43] W. C. Allee, *Proc. Cambridge Phil. Soc.,* 9: 1, p. 42, January, 1934.

[44] Royal N. Chapman and W. Y. Whang, *Science,* 80: 2074, p. 298, September 28, 1934.

[45] F. G. Holdaway, *Ecological Monographs* 2: pp. 282, 283, July, 1932.

but which apparently no one has collated or emphasized. It would take a book to do justice to knowledge of the subject, although the ratio of what we know to what we do not know about it is small indeed.

In the case of yeasts, experimental results with which have been referred to, accumulation of ethyl alcohol produced by the plants themselves is the limiting factor.[46] Certain protozoans exhibit a similar phenomenon in microcosms, and Woodruff, who studied them extensively, shows[47] that both paramecia and hypotrichs excrete substances which are toxic to themselves and which tend to inhibit the rate of reproduction.

The roots of numerous plants are known to produce deleterious secretions, Schreiner and Reed reporting that these excreta are most toxic to plants of the same species,[48] a conclusion later confirmed by Pickering.[49]

A great variety of self-limiting factors on populations may be cited more briefly. Every observer can corroborate some of them from his own experience and no doubt also can add to the list. The eating of eggs is a self-inflicted check on populations and is exemplified in diverse groups. The flour beetle (under experimental conditions) was instanced in the preceding section, and the habit has been noted in nature in the case of the potato beetle. Fishes are known to eat their own eggs and the practice is known in even so advanced a group as birds.

Excess oviposition by membracids kills the twigs in which the eggs are laid; these terminals then dry and shrink, thus destroying the embryos. "The insect is its own worst enemy."[50]

Devouring the young is known among insects (flour beetle, mole cricket), fishes (viviparous fishes, cod, trout, salmon), amphibians (salamanders), snakes and mammals. "Carnivorous males possess an instinct which prompts them to follow with expectancy the pregnant females before they have brought forth, and if they discover them, to devour the broods as soon as they are born."[51] In the London Zoological Gardens Superintendent Bartlett noted cannibalism as to young in the case of all carnivorous males except bears and in herbivorous males of prolific species.[52] Common observation proves it to occur not infrequently in certain domesticated mammals.

The shading out of their own seedlings by trees and other plants, another control exerted by adults against immature of their own kind, is a phenomenon annually occurring on a vast scale.

Infant cannibalism is known among mollusks, insects (dragonflies, flesh flies, flour beetles), spiders, fishes and salamanders.

Birds are known to indulge in a variety of practices which have the effect of limiting populations. In numerous species desertion of the eggs on slight provocation has been observed, and colonial birds such as pelicans have been known to abandon their eggs *en masse*. Certain birds, as cormorants, gulls, terns, herons and owls, begin incubation with deposition of the first egg; this results in the eggs hatching at intervals, in unequal growth of the young, and, in consequence, considerable mortality. Taverner notes with respect to double-crested cormorant that "in the latest stages observed we did not see a nest that contained more than one bird."[53]

46 G. F. Gause, "The Struggle for Existence," p. 75, 1934.

47 L. L. Woodruff, *Jour. Exp. Zool.*, 14: 4, 575–582, May, 1913.

48 O. Schreiner and H. S. Reed, *Bul. Torrey Bot. Club*, 34: 6, 279–303, June, 1907.

49 Spencer Pickering, *Ann. Bot.*, 31: 181–187, April, 1917.

50 M. A. Yothers, *U. S. Dept. Agr. Tech. Bul.* 402, p. 26, February, 1934.

51 George Paulin, "No Struggle for Existence. No Natural Selection. A Critical Examination of the Fundamental Principles of the Darwinian Theory," p. 51, 1908.

52 *Ibid.*, p. 38.

53 P. A. Taverner, *Canada Geol. Surv. Mus. Bul.* 13, p. 7, 1915.

Some birds normally have a conspicuous proportion of non-breeding individuals (e.g., scoters, shorebirds) while others breed at irregular intervals, as vultures. "Periodic extensive non-breeding is not uncommon in the arctic among certain birds."[54] These include loons, jaegers, gulls, ducks, geese, owls and others. Similar restrictive habits exist among mammals, that of individual non-breeding being well known in herding kinds, as sea-lions, and ruminants, and that of breeding at intervals of more than one year in bears and elephants.

Biennial fruit and seed production is a very common plant phenomenon (apples, oaks, mullen) and fruition at longer and irregular intervals also is well exemplified (pines, agaves, beech).

An evident safety-valve for populations that must be classed among the self-limiting factors is the habit of irruptive migration. Most of the individuals participating in these outbursts never return to the place of origin; in fact, in characteristic instances they make no effort to do so. Without doubt most of the individuals perish in a relatively short time and the breeding population is thus very effectively reduced. Some of the creatures exhibiting irruptive migrations are hawks, owls, sand grouse, sharp-tailed grouse, ptarmigan, the red-breasted nuthatch, squirrels, mice, lemmings, termites, ants, moths and butterflies.

Self-limitation of populations is so well recognized in the human race that we have familiar terms referring to its various phases, as contraception, abortion, infanticide, celibacy, polyandry and polygamy, not to mention a host of other practices not so widely accepted. It is apparent that self-limitation of populations is a wide-spread, it may be a universal, phenomenon. In most cases it can not be regarded as competition; in fact, it exemplifies what we find on due reflection to be the almost omnipresent evasion of competition.

W. R. Thompson says: "The simple truth is that the natural control of organisms is primarily due, not to any complex cosmic mechanisms or regulatory factors, but rather to the intrinsic limitations of the organisms themselves."[55] If this conclusion be accepted it means the death knell of the whole series of natural selection subtheories as to "protective adaptations," dependent, as they are, on a postulated high degree of "natural control" by selective predation.

The Malthusian Doctrine and Natural Selection

Malthus "later gained wider fame by being the acknowledged source of Darwin's long sought concrete cause of evolution, Natural Selection."[56]

> A chance reading of the *Essay* in which the phrase "struggle for existence" struck an answering chord, stimulated Charles Darwin to find the key to biological change in the process of natural selection brought about by this struggle for existence."[57]

> It is well known that he [Darwin] accepted the Malthusian view of over-population and deduced from it the struggle for existence. . . . He took his logical method from Malthus. He began from a single definite fact, based on observation, namely, that the number of individuals increases at a rapid rate. He considered what would be the result of this tendency should it act unchecked; he concluded that it would lead to a struggle for existence, and he called the deduction thus arrived at a natural law.[58]

Malthus was canny in expressing himself on the mode of increase; he says, for instance, in regard to the human race, that "population, *when unchecked,* goes on doubling itself," and in his more general statement, "the germs of existence contained in this earth, *if they could*

[54] G. C. L. Bertram, David Lack and B. B. Roberts, *The Ibis,* 13 ser., IV 4: p. 827, October, 1934.

[55] W. R. Thompson, *Parasitology,* 21: 3, p. 273, September, 1929.

[56] E. M. East, "Mankind at the Crossroads," p. 47, 1923.

[57] Reference No. 1, p. 745.

[58] E. Radl, "The History of Biological Theories," Transl. by E. J. Hatfield, pp. 17, 18, 1930.

freely develop themselves, would fill millions of worlds." As prophecies, such remarks are perfectly safe. They are not put to the test because populations always have checks; are rarely if ever able to develop freely.

The potentiality for rapid (if you will, geometric) increase of organisms is undeniable, but realization of that potentiality does not necessarily follow. It may be achieved at times by man and by domesticated and other organisms, profiting by man-made alterations of environments, but these occurrences can not be considered representative of what may happen under natural conditions. In nature, geometric increase only occurs subsequent to the low point in cyclic or other severely fluctuating populations, and in those is promptly checked as the average maximum abundance of the species is again approached.

As has been pointed out,[59] selectionists have been rather naive in their disquisitions on populations, which although essentially stationary yet are said to be increasing at a geometric rate. Wallace, for instance, says: "As all wild animals increase in a geometrical ratio while their actual numbers remain on the average stationary, it follows that as many die annually as are born."[60] And in another connection: "We must never for an instant lose sight of the fact of the enormously rapid increase of all organisms. . . . Then, never forgetting that the animal and plant population of any country is, on the whole, stationary, we must be always trying to realize the ever-recurring destruction of the enormous annual increase."[61]

Now it is manifest that both of these propositions as to populations can not be true. If the population is stationary, it can not be increasing at a geometric rate, or if it has the latter attribute it can not be stationary. Although populations fluctuate, often abruptly, the average, so far as we can tell, remains about the same over long periods. From a subsistence standpoint this can only mean that the average consumption of food is about the same from year to year.

Further implication of this state of affairs is that food as a rule being in excess (as shown in a preceding section), and the quantity required remaining about the same from year to year, there can not be as a rule any broadly significant competition for food or sustentative selection in a state of nature.[62]

Since food as a rule is in excess and populations in the long run hold to average numbers, it is evident that they are checked short of a subsistence limitation. "If they could multiply unchecked, that is, without the loss of many of their progeny, every species would fill up its area of occurrence and exhaust the whole of its food supply, and thus bring about its own extermination. This seems to be prevented in some way, for as a matter of fact it does not happen."[63] The phenomenon is another of the apparently automatic devices of nature for preserving numerical relationships, the real essence of which seems to elude comprehension.

If sustenance is not the limiting factor, as seems clearly to be the case in general, inquiry immediately arises as to what is. The writer is not one of those who believes that everything can be explained; the matter can, however, be discussed. Besides subsistence effects we have in previous pages dealt also with space effects. The question relative to them that is pertinent to the present section

59 Charles Clement Coe, "Nature versus Natural Selection: An Essay on Organic Evolution," pp. 43–59, 1898.

60 A. R. Wallace, "Contributions to the Theory of Natural Selection. A Series of Essays," p. 309, 1870.

61 A. R. Wallace, "Darwinism: An Exposition of the Theory of Natural Selection with Some of Its Applications." Ed. 2 (Reprint with corrections of edition 1 (1889), p. 122, 1890.

62 Roswell H. Johnson, *Am. Nat.*, 46: 546, 372–376, June, 1912.

63 Reference No. 15, p. 44.

is whether, in their working out, a struggle for existence and survival of the fittest are apparent.

For a beginning it may be pointed out that the space effect or limitation of population, as density increases, characteristically operates through a lowered rate of reproduction. This phenomenon is far from according with the postulated geometric increase and intensified mortality called for by the Malthusian principle of population and the Darwinian theory of natural selection.

Even if birth rates do decrease, however, a reproductive excess always remains and we may inquire whether the normal process of its disposal seems to bring into play a struggle for existence and a survival of the fittest. In the case of short-lived organisms, where the parent generation has passed before the filial generation matures or is even born, elimination proceeds until, on the average, there are just enough of the new generation left to replace the old. In the case of longer-lived forms where the parent generation may live concurrently with the new, elimination is even more severe, leaving only enough young ultimately to replace the number of the old that perish in the average span of a generation. In either case mortality is conspicuously greater among the young, and as a rule the rate of elimination is directly proportional to the degree of immaturity.

The losses in the egg stage of animals and in the seed or spore stage of plants are well known to be excessive. Many birds, for instance, suffer from 50 to 75 per cent. destruction of eggs. That fitness, at least of the eggs, is not the cause is shown by experience with game species that are artificially propagated. In the case of the bob-white, for example, with about 64 per cent. of nest (and presumably therefore of egg) destruction in the wild, from 75 to 85 per cent. of the eggs can be hatched under bantams or in incubators.

Tremendous losses in the egg stage of various animals are so familiar a phenomenon that few instances need be cited. The mass destruction that often overtakes the eggs of frogs, toads, salamanders and of various insects that oviposit in temporary pools is known to all observers. Here again total annihilation by the drying up of the pools is in no way affected by "fitness" of individuals. It is conceivable that partial elimination might be so affected, but where destruction occurs it is usually complete.

When miles long ridges of pelagic ova are destroyed by being washed up on shore, when the eggs of a multitude of parasitic forms perish by the thousands because they have not had the luck to find a host, when annual crops of seedlings are all suppressed in forests for decades, perhaps, until there is a chance opening in the canopy from which as seeds they fell, it is idle to speak of the "survival of the fittest." It would be easy to catalog case after case of excessive egg, seed or spore production cut down promptly in those or in immediately succeeding stages, but it is unnecessary as the phenomena of which examples are here given are recognized as being the rule in nature. In fact, the normal process seems to include tremendous elimination of the young with an intensity proportional to their immaturity; this in itself goes far to insure little increase in demand either for food or space (*i.e.*, the period when the population is really above normal is very brief compared to the length of a generation); there is subsequent survival of a very high proportion of those escaping the early sweeping destruction, these survivors mostly living to propagate their kind. In other words, there seems to be a relatively small proportion of the total elimination (hence selection) among those that mature and provide for continuity of the race.

From prevailing accounts of natural

selection we are led to think that it is the result of competition between evenly matched individuals, in which "a grain in the balance may determine which individuals shall live and which shall die."[64] Since, as we have just noted, however, a high proportion of mortality occurs in the immature stages and few therefore attain the adult state, there is little or no chance for competition of the oncoming with the outgoing generation even in cases where they are alive at the same time. To refer to the usual sweeping elimination of inert eggs and helpless babes as a struggle for existence is a travesty. These immature forms have no power to resist; they merely await their fate, and whether that fate is life or death in a great majority of cases does not depend on individual qualifications. The weight of evidence indicates that the elimination of the immature is highly indiscriminate and that the survivors are the lucky rather than the "fit."

Conclusions

Superficially considered, the Malthusian principles seem very impressive, but they do not bear analysis. It is manifest throughout nature, and even in the highly artificial case of humankind, that populations are not necessarily limited by the means of subsistence, and that they do not always increase where the means of subsistence increase. Malthus mentioned but did not dwell upon limitations of space. These are important, and in a broad sense controlling, but they also do not ordinarily depend upon subsistence.

Malthus's postulated geometric increase of population is not the rule in nature; it is merely a potentiality, rarely realized. Populations usually are checked far short of a subsistence limitation. Automatic restriction by lowering of birth rate in response to density and by a great variety of self-limiting phenomena, together with sweeping indiscriminate destruction of immature forms, involving little or no actual competition either among themselves or with adults, seem to be the principal factors involved in maintaining the stability of populations. These facts leave so little basis for the Darwinian theory of natural selection, largely inspired by the mistaken postulates of Malthus, that it is difficult to understand its popularity.

The more we learn about organic populations, the more it seems that there are automatic tendencies toward the preservation of numerical relationships. This automatic regulation is not rigid, the balance of nature is fluctuating, but it is always striving for equilibrium. Man may not want to admit the principle of automatic population control, as so doing interferes with his playing with the idea that ultimately he can explain it all—an idea to which the writer does not subscribe.

64 Charles Darwin, "The Origin of Species by Means of Natural Selection or the Preservation of Favored Races in the Struggle for Life," Reprint 6th Ed., pp. 454–455, 1912 (?).

SCIENCE SERVICE RADIO TALKS

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CARE OF THE HEALTH IN HOT WEATHER

By Dr. ROBERT OLESEN

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WHILE the underlying principles of personal hygiene observe the same general trends at all times, the actual measures to be instituted vary somewhat in kind and degree with the seasons. This is particularly true during hot weather, when certain alterations of conduct are desirable if unnecessary discomfort or actual illness is to be avoided. However, there is no new or startling advice, instruction, rule or magic formula for safeguarding the health at such times. Health maintenance is primarily an individual responsibility, the essential factors usually being simple, accessible and practical. Hot weather hygiene may be expressed in a single word—moderation.

In summer one's thoughts naturally and very properly turn to the prospect of a vacation, with a change of scene and respite from customary occupations. The wise employer, realizing that mutual benefits will accrue, insists that full and continuous vacations be taken by his employees. Quite obviously every person, whether employed or not, would be benefited by a change of environment. However, for financial or other reasons, many persons are unable to spend the entire warm season or even a small part of it, in a sojourn away from home.

There are numerous compensations for the person who must remain at home during summer. First and foremost is the fact that the local health department is or should be continuously providing health safeguards. In cities the milk, water and food supplies are usually carefully supervised. Moreover, modern sewerage facilities are available and insect pests are infrequent. The freedom of one's own home and proximity to personal possessions are likewise conducive to comfort and enjoyment. There are times when a vacation at home affords the best possible opportunity for rest and recuperation. However, many of these home advantages are offset by the intensity of the summer heat and the sameness of the surroundings.

When an "away from home" vacation is decided upon adequate health protection should be a prime consideration. The selection of a suitable vacation place is an important matter requiring the exercise of good judgment and careful attention to numerous vital health factors. Thus, safe milk and water, wholesome food, restful surroundings and opportunities for zestful recreation should be insisted upon. The onset of the hot season is a signal for greatly reduced mental and physical activity—a time for recharging the human "battery."

The vacation should be a time for rest and recuperation as well as for pleasurable refreshment of the strength and spirits. To make this period so strenuous that one returns to his customary duties completely fatigued can scarcely be termed sensible or profitable. Furthermore, full advantage should be taken of the opportunity for exercise in the open. To remain indoors constantly, to spend an excessive amount of time at the card table or to keep unnecessarily late hours is to defeat the object of the vacation.

But whether the heated term is spent

in customary surroundings or away from home there are certain hygienic principles that can, with profit, be observed. On very hot days it is a wise general rule materially to reduce the mental and physical speed at which the individual customarily operates. This injunction is particularly applicable to workers of all kinds, both in offices and in the open. Considering the relatively small amount of work performed under adverse conditions it is often justifiable to curtail the working hours during excessively hot weather. Such expedients as short rest periods, cooling drinks, protection from direct rays of the sun and cooled work places are reflected in the increased comfort, contentment and increased efficiency of the favored workers.

It is fortunate that hot weather fosters a disinclination for heavy and hot meals because light, nutritious and easily digestible food is obviously more suited to the season. Generally speaking, fried foods, pastries, excessive amounts of sweets and other articles contributing materially to heat production should be curtailed. On the other hand, fresh ripe fruits, fresh garden vegetables, salads, cereals, milk of good sanitary quality and milk products satisfy the hunger while contributing but little to heat production. Even so the diet should be properly balanced by partaking in moderation of standard articles of food. When meals are eaten unhurriedly in cool, pleasant and inviting surroundings the appetite is stimulated and the digestion is aided. Furthermore, the jaded summer appetite may be spurred when artistry and imagination are used in preparing and serving food.

An abundance of water, internally and externally, is a necessity during hot weather. One or more tepid tub baths or cool showers daily cause discomfort and fatigue to be replaced by a feeling of well-being. A swim in a pool or a body of water of good sanitary quality is cleansing, cooling and provides needed exercise that might not otherwise be obtained.

Just how much water should be consumed in hot weather depends largely upon the work performed, the atmospheric temperature and the relative humidity. In any event pleasantly cool water should be consumed in fairly liberal quantities but not too hastily. The excessive use of iced or sweetened drinks is apt to exert a detrimental influence upon the digestion.

It seems almost superfluous to reiterate that summer clothing should, for the comfort of the wearer, preferably be light in weight and color and porous in texture. Such clothing permits evaporation of perspiration and allows air to reach the skin readily. Frequent changes of clothing, particularly of that next to the skin, is especially conducive to comfort. It is earnestly to be hoped that before long men may share some of the comforts now monopolized by women. Thus, the discarding of coats, vests, collars and ties would add greatly to masculine comfort while not too severely outraging the dictates of fashion and good taste.

The keeping of late or irregular hours during the summer is particularly undesirable and even harmful, for health maintenance requires an adequate amount of sleep. Because of intense heat, especially at night, it is sometimes difficult to secure the requisite amount of refreshing and untroubled sleep. At such times an electric fan may be of value. However, the air currents produced by the fan should not be permitted to play directly upon the body, lest chilling and illness occur. The siesta or midday nap, a fixed habit in tropical countries, is a valuable aid in insuring adequate rest during hot weather. Whether one actually sleeps, reads or

lies quietly for a short time in a darkened room, this brief respite from routine affairs is an excellent "shock absorber." In any event it is wise to allot regular and sufficient time for sleeping purposes.

Summer is not a time for excessive activity. Quite on the contrary exercise suited to the occasion, as well as the requirements of the individual, should be sought. Constant automobile riding is strongly to be deprecated, especially when interspersed with irregular hours, injudicious eating and insufficient exercise. Moderate indulgence in walking, swimming, dancing, golf, tennis, horseback riding, archery, quoits and similar diversions will provide pleasant and needed exercise during hot weather. However, participation in these sports may well be confined to the early morning and later afternoon, when the heat of the sun is less intense.

Swimming, one of the most popular of summer sports, has been greatly abused by the careless and unthinking. It is obvious that so useful a diversion should be surrounded with adequate safeguards. Ability to swim and knowledge of rescue methods are prime requisites for entering the water. Needless to say, water used for bathing should be free from pollution lest disease be widely disseminated. By refraining from bathing immediately after eating, remaining in the water only for short periods and avoiding chilling of the body, this excellent sport may be enjoyed without fear of unfavorable reaction.

A coat of tan should be acquired gradually, otherwise one may suffer unnecessarily and even intensely from sunburn. The bronzed skin of the lifeguard may well be envied, but it should be remembered that a healthy tan is the result of weeks of gradual exposure to the sun rather than an intensive burn acquired during a day's sojourn at a bathing beach.

As the mind, as well as the body, is in need of periodical rest and diversion, an admirable opportunity is afforded during the summer for mental hygiene. The reading of light, diverting and not too stimulating literature is often soothing and conducive to a feeling of well-being. By substituting new, interesting and less exacting mental activities for those customarily pursued interest and enjoyment can be induced. Satisfactory mental rest can often be secured easily and naturally by working with the hands instead of the head. Indulgence in a hobby is an excellent way of mitigating the discomforts of heat. Thus, the identification of birds, trees, flowers, plants and insects may be cited as useful and diverting interests. There are many hobbies that are not strenuous in their demands, yet provide mild, soothing and helpful mental exercise. Such relaxation is particularly relished by a person who is ordinarily engulfed by concentrated mental requirements.

Comfort during hot weather is due in no small part to a complacent mental attitude. A philosophical state of mind, freedom from worry and inclination to benefit as much as possible by the respite from ordinary duties are all conducive to health and happiness. When an unruffled state of mind is coupled with reasonable observance of hygienic principles a winning combination results. Moreover, when the summer season has been properly spent the arduous duties of fall and winter may be resumed, with confident assurance that the mind and body are better prepared to meet the more exacting demands that will almost certainly be forthcoming.

THAT PERENNIAL PUBLIC ENEMY, POISON IVY

By Dr. JAMES F. COUCH
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VACATION days will soon be here again, and the great outdoors, with its green meadows and purling brooks, its wooded dells and surfy shores, beckon irresistibly to the nature lover. Gladly humanity responds to the invitation and pours out of the sweltering cities into the cool calmness of the countryside. Most of these people will return refreshed and recreated by the holiday; some, however, will encounter that perennial public enemy, poison ivy or poison oak, with the result that their vacation will be turned into a period of acute suffering from the effects of that pest. A few will escape with nothing worse than some intensely itching blisters, but some will suffer a general reaction to the poison, accompanied by swelling of the affected parts, chiefly the face and hands, and the extremely susceptible will be made so acutely sick as to be confined to bed for several days. Ivy poisoning is always discomforting and may become very serious. Four cases of death have been reported, which indicates that it is not to be considered merely a trivial affection.

Ivy poisoning always results from direct or indirect contact with the plant and the easiest way to avoid it is to learn how to recognize the plant and then to keep away from it and from anything else that may have been in contact with it. Dogs and cats may run through patches of poison ivy and brush off the poison on their fur. Susceptible persons who may then pet these animals are very likely to contract a case of ivy poisoning without having been anywhere near the plant.

Poison ivy is classified by botanists in the genus *Rhus*. About twenty species of this genus are known to cause the characteristic dermatitis. Many other species of *Rhus,* like most of the common sumacs, do not cause this dermatitis. Of the poisonous species, three are of especial note. Two are of shrubby growth but may be found climbing upon walls and trees, like the true ivy. In the East the principal dangerous species is *Rhus radicans* L. and is popularly called poison ivy. It is also called poison creeper, markweed, mercury, picry and three-leaved ivy. Some confusion is caused by the fact that the name poison ivy is applied in some sections of the South to mountain laurel, a plant that does not cause inflammation of the skin or dermatitis.

In the Mountain and Pacific Coast states grows another shrubby species, *Rhus diversiloba* Torr. and Gray, which is commonly known as poison oak, a name that is often used also to designate the Eastern poison ivy. The third poisonous species is *Rhus vernix* L., known as poison sumac, and also called swamp sumac, poison ash, poison elder, poison dogwood and thunderwood. This species grows in bogs only and so is less accessible and causes less trouble than the other two. Poison sumac grows as a tall shrub or sometimes as a tree 20 to 30 feet tall. Poison ivy is really misnamed. The true ivies are not poisonous to the touch, but Captain John Smith, of Jamestown fame, after a painful experience with the plant, fancied that *Rhus radicans* resembled English ivy and gave it the name by which it has gone ever since.

Poison ivy and poison oak can easily be recognized by the characteristic form of the leaf, which is divided into three leaflets and accounts for the wholesome maxim "Leaflets three, let it be!" After

the leaves have fallen in the autumn, the plant is still dangerous and may then be detected by the white berries that remain well into the winter. Virginia creeper is often mistaken for poison ivy, but here the leaf is divided into five leaflets instead of three. Virginia creeper does not cause dermatitis.

In swamp sumac the leaf is divided into 7 to 13 leaflets instead of three, and these are 3 to 4 inches long with a scarlet-colored midvein. The arrangement of the leaflets is like that found in other sumacs. I would suggest that you get some illustrations of these plants and familiarize yourselves with their appearance so that you may readily recognize them. A number of excellent pictures of the poisonous *Rhus* are published in Farmers' Bulletin No. 1166, issued by the United States Department of Agriculture, and serve well to identify these plants.

Poison ivy, poison oak and poison sumac all contain a milky juice that is very irritant and can blister the skin on contact. I doubt if any one is immune to this poison, although some people are much more resistant than others. Some are so susceptible that the slightest contact seems sufficient to cause a severe reaction. There does not seem to be any foundation for the stories that certain races, like the Indians, are immune to ivy poisoning. Even those who are quite resistant will be blistered if the juice of these plants comes in contact with tender skin and is not washed off before it penetrates. Persons who are relatively non-susceptible should, nevertheless, treat poison ivy with respect because repeated contact with the plant is known to sensitize the body to the poison so that a resistant person may become very susceptible in time.

A number of cases of *Rhus* dermatitis has been reported in which the irritation was contracted by handling articles decorated with Japanese lacquer. This lacquer is made from the juice of a species of *Rhus* that grows in China and Japan. The sufferers developed typical cases of ivy poisoning after contact with these articles. However, these articles will affect only the most sensitive persons and are quite safe for most people to handle.

Occasionally there is a report that some animal has been poisoned by poison ivy, but this is rare. Probably the fur of most animals prevents the irritating substance from reaching the skin and so protects them. Cattle and sheep graze upon poison ivy with apparent impunity and it seems to be true that the poison does not affect the mucous lining of the gastro-intestinal tract.

It is said that a person sensitive to ivy poisoning may render himself immune for a season by eating three of the leaves in the spring. This report comes from a variety of sources and may have some foundation. However, a few cases are on record in which persons who ate poison ivy leaves were made sick, and Dr. J. B. McNair, in his exhaustive book, "Rhus Dermatitis" (University of Chicago Press, 1923), records the deaths of two children from eating the berries. There is a story that the Indians of the Pacific Coast used this method and never suffered from ivy poisoning, although they roamed the mountains during the summer without much clothing on, and poison oak grows very luxuriantly in those localities. A method for immunizing people based on this idea has been developed by a member of the medical profession, and good results have been claimed for it.

The isolation of the peculiar irritant poison of these plants early challenged the skill of our chemists and it was soon found that this is no common sort of poison but something that is very elusive and, once separated from the plant, readily changes into other forms so that the task of isolating it in a pure condition is extremely difficult and requires the utmost patience and dexterity. We have the results of a large number of investi-

gations of this poison that give us much information concerning it. Poison ivy was studied by Pfaff[1] and by Acree and Syme.[2] A thorough study of poison oak was made by McNair,[3] and poison sumac was investigated by Stevens and Warren[4] and by Warren.[5]

All these chemists obtained from the plants oily substances that were very toxic and would produce blistering in incredibly small quantities. The poison was named "*toxicodendrol*" by Pfaff and appears to be present in all species of *Rhus* that cause dermatitis. It is present in the roots, stems, leaves and berries, although the ripe berries are said to be practically non-poisonous. Toxicodendrol, literally "the phenol from the poison tree," is a complex substance that belongs to the group of substances called phenols by the chemist. There are other members of this group that can blister the skin, but none is known that is so active as this one from poison ivy. Toxicodendrol is readily soluble in fats and so easily penetrates to the lower layers of the human skin, where it sets up the painful irritation so well known to its victims. This action has even been patented in the United States by some enterprising gentleman, who developed a blistering lotion of which the active ingredient is toxicodendrol.

Evidently the best method to use in dealing with this irritant pest is to avoid it and escape its effects. Poison ivy, however, is so ubiquitous and grows so often in dark and shaded places where it is not easily recognized that it is not always possible to evade it. When it is growing along paths, by the roadside, in the garden or near the house where it is difficult to avoid it, the plant should be eradicated. This can be accomplished by digging it out by the roots, which is the most effective method of disposing of it permanently. However, if you do not care to get so close to the pest as digging requires, other methods are available. These are fully described in Farmers' Bulletin No. 1166, already referred to, a copy of which should be available to every one interested.

Let us suppose that you have come into contact with poison ivy. What are you going to do about it? The best method is to wash the exposed areas of the skin immediately with soap and hot water. Yellow laundry soap is recommended as best, since this contains an excess of alkali which dissolves the poison. It is advisable for sensitive persons to take this precaution after every trip through the fields where poison ivy may grow, whether actual contact has taken place or not. Sometimes sensitive persons on a scientific excursion or in pursuit of their business affairs may find it necessary to pass through areas where poison ivy is growing, and it is desirable that these persons have some type of protection. Dr. McNair suggests that the hands and arms be bathed in 5 per cent. solution of ferric chloride in equal parts of glycerin and water before the sensitive person ventures into the infested places. Another preventive suggested is to bathe the exposed parts of the skin with a 5 per cent. solution of copperas or ferrous sulfate before visiting those areas. One should always remember that in the majority of cases it is the hands that come in contact with the poisonous plant. The hands get covered with the poison, which is then carried to any other portion of the body that the hands may happen to touch. If one suspects that he has touched poison ivy, he should be careful not to spread the poison by rubbing his face or arms or touching any other part until he has thoroughly washed the poison off his hands.

After contact the rash or blistering may begin to appear within a few hours to two or three days. Reddish blotches or wheals that itch distractingly or multi-

1 *Jour. Exp. Med.*, 2, 184, 1897.
2 *Am. Chem. Jour.*, 36, 391, 1906.
3 *Jour. Am. Chem. Soc.*, 43, 159–64, 1921.
4 *Am. Jour. Pharm.*, 79, 499–522, 1907.
5 *Pharm. Jour.*, 83, 531–2, 562–4, 1909.

tudes of small itching blisters make their appearance and tempt one to ease the torment by scratching the skin. Scratching is to be avoided because it spreads the poison and at the same time breaks the outer layer of cuticle and allows the poison ready access to the lower layers of the skin. A large number of remedies has been suggested, and in particular cases many of these are successful. In my own experience I have found an oxidizing agent is the most rational and satisfactory treatment. Toxicodendrol is very susceptible to oxidation and if brought into contact with some substance capable of liberating oxygen it will be converted into an inert resin that can not cause blistering. One of the cheapest, most common and harmless oxidizing agents is potassium permanganate, which may be obtained at any drug store. In a strength of five per cent. in water potassium permanganate stops the itching almost immediately by destroying the poison and so gives quick relief. It may be applied as a wash using a piece of absorbent cotton or cloth and dabbing it on the affected spots until the itching stops. Blisters should be opened with a sterile needle to allow the remedy to come in contact with whatever poison may be contained inside them.

This remedy was suggested seventy years ago by John M. Maisch, of Philadelphia,[6] and is still the standard treatment. It has one disadvantage. As it gives up its oxygen, potassium permanganate turns brown and leaves a brown stain on the skin. This should be washed immediately after each application. The stain may be removed slowly by washing with soap and water or more quickly by a one per cent. solution of oxalic acid or by sodium bisulfite, sodium hyposulfite of the photographers or by hydrogen peroxide, although the warmth occasioned by the last mentioned may be disagreeable to some people. The oxalic acid will cause a stinging of raw surfaces which, however, is mild and not objectionable to most persons.

Generally one thorough application of potassium permanganate is sufficient but stubborn cases may require several applications. The permanganate is harmless to the most delicate skins, particularly if the skin be washed thoroughly after each application. After itching has stopped the affected area should be allowed to heal under antiseptic conditions. A soothing ointment such as zinc oxide or boric acid ointments should be spread gently over the skin to assist nature in repairing the injured tissues. But an ounce of precaution is always worth a pound of cure. Learn to recognize the plant and keep away from it.

[6] *Proc. Am. Pharm. Assoc.*, 13, 166–74, 1865.

DR. JOHN GORRIE—INVENTOR OF ARTIFICIAL ICE AND MECHANICAL REFRIGERATION

By Professor GEORGE B. ROTH

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THE proclamation by the governor of Florida[1] of the week of August 11 to 17 as "Ice Memorial Week" had associated with it the name of an early distinguished and eminent Southern practitioner of medicine, Dr. John Gorrie, of Apalachicola, Florida.

Relatively few medical men outside of the state of Florida have ever seen his name, although the state of Florida about twenty years ago placed a statue of Dr. Gorrie in Statuary Hall of the Capitol of the United States.[2]

The accomplishments of Dr. Gorrie were not wholly in the realm of medicine, the memorial in Statuary Hall representing his ability as an inventor rather than as a practitioner of medicine, having been placed there largely through the efforts of those interested in ice manufacture and mechanical refrigeration to commemorate his invention of the ice-machine.

The patent, No. 8080, which was granted Dr. Gorrie on May 6, 1851, is considered to be the first U. S. patent on an apparatus for the mechanical production of ice, the previous patents being non-workable.[3]

Dr. Gorrie's apparatus was based on the well-known law that the release of a compressed gas (in this case, air) results in the absorption of heat.

Dr. John Gorrie was born in Charleston, S. C., on October 3, 1803. His early education was obtained in the schools of that city; his medical education from a Northern institution. His biographers[4] state that he received the degree of doctor of medicine in 1833 from the College of Physicians and Surgeons of New York City, a statement which can not be verified, as the name of John Gorrie is not to be found in the list of graduates for 1833 from that institution, nor in fact in its "Index to Alumni up to 1880."

Within a year after graduation he went to Apalachicola, Florida, which was then an important seaport, being the outlet for all the cotton grown in the Chattahoochee Valley in Georgia and Alabama. Here he resided until his death in 1855. He at once became a central figure in the life of Apalachicola, becoming postmaster in 1834 and retaining the position until 1838. He was a member of the city council and city treasurer from 1835 to 1836, mayor in 1837. In 1839 he withdrew from public office to devote his whole attention to medicine and investigation.

The greatest drawback to the growth of Apalachicola was the prevalence of fever in summer, and to this he gave his thought. He found it impossible to successfully treat his fever cases during the hot months. Believing that the excessive heat was the largest obstacle which he had to combat in his fight against fever, he devoted all his energies to air-cooling the rooms in the hospitals for his fever patients. This led to the development of the ice-machine, ice being necessary to air cooling and air conditioning. Under the nom de plume of "Jenner" he is said to have written a series of eleven articles in 1844 for the *Commercial Advertiser* of

[1] *Jour.* Am. Med. Assn., 105: 441, 1935.

[2] "U. S. Statutes at Large," Vol. 38, Pt. 2, p. 1615; also *Ice and Refrigeration*, 46: 311, 1914.

[3] *Ice and Refrigeration*, 21: 45, August, 1901.

[4] "Dictionary of American Biography," Vol. 8, p. 436; also *Ice and Refrigeration*, 46: 311, June, 1914.

Apalachicola, on the prevention of malarial diseases. A paper in the *New Orleans Medical and Surgical Journal*[5] on "The Nature of Malaria and Prevention of its Morbid Agency," is of interest in connection with the modern movement towards air conditioning sick rooms and hospitals, since he gives in detail the method which he employed and which undoubtedly led to the invention of the ice-machine as a by-product.

In this paper he wrote about malaria as follows (page 767):

> Although we know nothing certain of the elementary character of malaria, yet it is generally believed, and has been abundantly proved, that the circumstances essential to its existence are organic decomposition, moisture and heat.

For its prevention he used the following means (page 758):

> The mechanical contrivance by which I propose to take advantage of these properties of ice, so as to effect a refrigerating and depurating ventilation, is . . . simple. My whole process consists in first suspending an ornamental mantel vase, urn or basin, in which the ice is placed, by chains like a lamp or chandelier, from the center of, and close to the ceiling of a room. Next, over this vessel an opening is made in the ceiling from which a pipe is extended, between the ceiling and the floor above, to the chimney of the house . . . through it (chimney) and the pipe, instead of the doors and windows, all the air as far as possible . . . ought to be received. In such an arrangement the external and fresh air is attracted . . . to the upper part of the room, in consequence of the partial vacuum formed around the ice, and thence, after being cooled, it is dismissed in a diffused shower . . . to the floor to be discharged by the lower pipe.

His explanation of the beneficial effect of this procedure is as follows:

> The solution of ice . . . is attended with a number of chemical actions on air . . . and are all concurrent on one grand effect—the decom-

[5] *New Orleans Medical and Surgical Journal*, 1854–1855, pp. 616–634, 750–769.

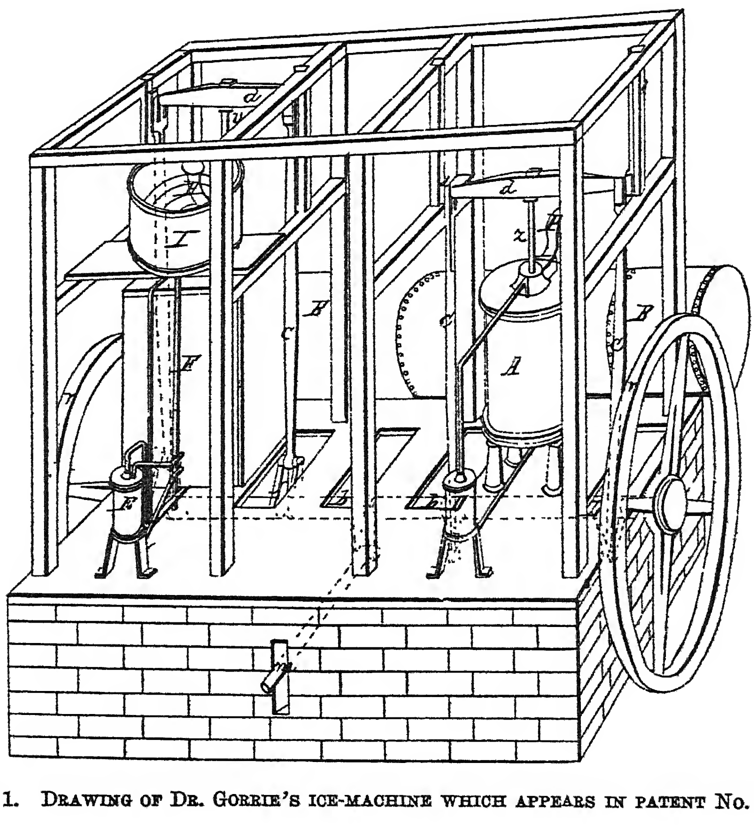


Fig. 1. Drawing of Dr. Gorrie's ice-machine which appears in patent No. 8080.

position of Malaria; mixed with warmer air, it reduces its temperature and in the same process causes it to deposit its continued vapor in the form of water; and, at the same time, it absorbs other volatile matters and extraneous gases contained in the air. Receiving, as part of the device, the air intended to be acted upon through a long conduit like a chimney, lined with carbon dust in the form of soot, must also tend, from the affinity of carbon for vapors and organic oils, to decompose Malaria.

He further mentions in this paper having invented a machine for manufacturing ice, as well as explaining its principle and construction.

The patent on the ice-machine was issued to John Gorrie of New Orleans, the reason for this being that he was obliged to go to New Orleans to secure funds necessary to perfect his machine and make application for the patent.

The model of the ice-machine which Dr. Gorrie submitted to the Commissioner of Patents to secure his patent now resides in the U. S. National Museum. It is lacking in some of its minor parts.

Fig. 1 is a drawing of the machine which accompanied the application and which appears in the original patent, together with seven other views of it.

Fig. 2 is a photograph of the model as it now exists in the U. S. National Museum. Both Figs. 1 and 2 show the machine as viewed from the front.

The essentials of the machine are clearly brought out in the patent, which stated them as follows:

It is a well-known law of nature that the condensation of air by compression is accompanied by the development of heat, while the absorption of heat from surrounding bodies, or the manifestation of the sensible effect, commonly called "cold," uniformly attends the expansion of air, and this is particularly marked when it is liberated from compression.

The nature of my invention consists in taking advantage of this law to convert water into ice artificially by absorbing its heat of liquefaction with expanding air. To obtain this effect in the most advantageous manner it is necessary to compress atmospheric air into a reservoir by means of a force-pump to one eighth, one tenth or other convenient and suitable proportion of its ordinary volume. The power thus consumed in condensing the air is, to a considerable extent, recovered at the same time that the desired frigorific effect is produced by allowing the air to act with its expansive force upon the piston of an engine, which, by a connection with a beam or other contrivance common to both, helps to work the condensing-pump. This engine is constructed and arranged in the manner of a high-pressure steam-engine having cut-offs and working the steam expansively. When the air, cooled by its expansion, escapes from the engine, it is made to pass round a vessel containing the water to be converted into ice, or through a pipe for effecting refrigeration otherwise, the air while expanding in the engine being supplied with an uncongealable liquid whose heat it will absorb, and which can in turn be used to absorb heat from water to be congealed. By this arrangement I accomplish my object with the least possible expenditure of mechanical force, and produce artificial refrigeration in greater quantity from atmospheric air than can be done by any known means.

The apparatus for producing the refrigeratory effects before stated consists, essentially, of a large double-acting force-pump, A, with its jet-pump D, Figs. 1 and 4, condensing-tub R, and worm P, as represented in the drawing No. 4, a reservoir, B, made of such metal in the manner of a steam-boiler, a double-acting expanding-engine, C, provided with cut-offs, a jet-pump, E, a tub, I, and worm H, for cooling water, the engine C and the chamber G above it being inclosed in an insulating-box, F, which box, together with the worm and tub H, are inclosed in a second insulating room or chamber, K. The pumps, engine, and other moving parts are provided with the necessary mechanical appliances for putting and keeping them in motion and connecting them with the prime mover, which may be either a steam-engine or other available power.

In 1854 Dr. Gorrie issued a 15-page pamphlet (printed by Maigue and Wood of New York) entitled "Dr. Gorrie's Apparatus for the Artificial Production of Ice in Tropical Countries." In it he describes and illustrates the apparatus with a view to its sale for commercial purposes.

He states that he had appointed Mr. Henry E. Roeder, an engineer of New York, his general agent, from whom further particulars regarding the invention and its price could be obtained.

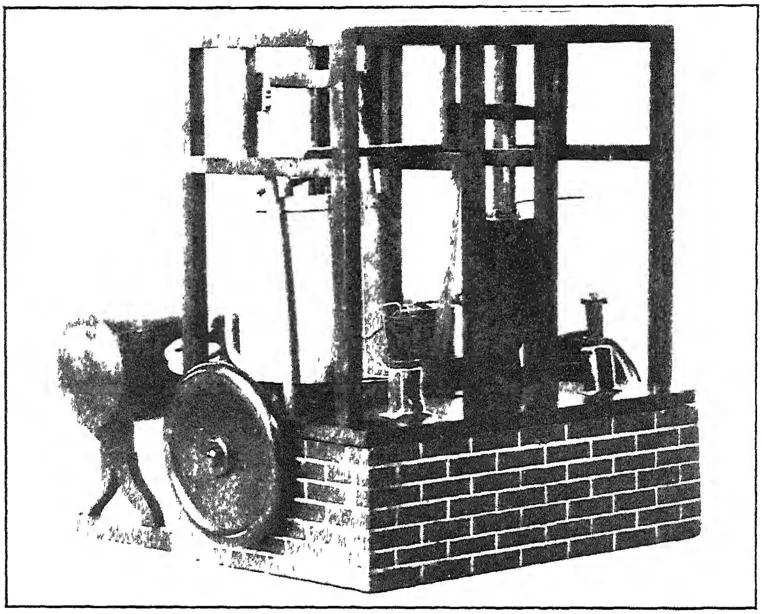


FIG. 2. PHOTOGRAPH OF DR. GORRIE'S MODEL SUBMITTED TO THE U. S PATENT OFFICE, AS IT EXISTS TO-DAY

His chief biographer, Mr George A Whiteside,[6] states that Dr. Gorrie virtually abandoned his practice in 1844. At this time having exhausted all his means, he went to New Orleans to get capital to build a large machine He then sold a half interest in the project to a man from Boston, who died shortly thereafter Unable to interest others in the commercial use of the machine and being penniless he returned to Apalachicola, where he began to brood over his failure to attain commercial success. Remaining almost entirely secluded at his home, he finally became sick, from which he failed to recover, his death occurring on June 18, 1855, after a short illness, at the early age of 52 He was buried, "agreeably to his expressed wishes, upon the beach of the beautiful bay of Apalachicola," in the old beach cemetery. Many years later, in 1893, his remains were disinterred and placed in the present municipal cemetery where they rest to-day.

Dr. Gorrie's scientific papers apparently were not numerous, although a gifted writer The publications available to-day are to be found in *Silliman's Journal of Sciences and Arts* and the *New Orleans Medical and Surgical Journal.* The paper in *Silliman's Journal* (1850, X, pages 39–49, 214–227) was entitled, "On the Quantity of Heat Evolved from Atmospheric Air by Mechanical Compression " In the first part of this paper he describes the plan and illustrates a machine for compressing air up to 8 atmospheres.

Previous to his paper on the nature of malaria which appeared in the *New Orleans Medical and Surgical Journal*, there appeared another in 1854 in the same journal (1853–4, Vol 10, pages 584–602, also pages 738–757) entitled "An Inquiry, Analogical and Experimental, into the Different Electrical Conditions of Arterial and Venous Blood " He found that "the normal electrical condition of arterial is one of higher tension than that of venous blood "

[6] *Ice and Refrigeration*, 12: 351, 1897.

FIG. 3. STATUE OF DR. GORRIE, IN STATUARY HALL OF THE CAPITOL OF THE UNITED STATES.

This paper, as the following quotations will bear testimony, definitely places him in the class with the modern physician of the investigative type.

> Physiology is the basis of all medical improvement and in precise proportion as our survey of it becomes more accurate and extended, it is rendered more solid.

> The wonderful structure of the animal system will probably never permit us to look upon it as a merely physical apparatus, yet the demands of science require that the evidently magnified principles of vitality should be reduced to their natural spheres, or if truth requires, wholly subverted in favor of those more cognizable by the human understanding. The spirit of the age will not tolerate in the devotee of science a quiet indifference. . . .

> From the physician, as emphatically the student of Nature, is expected not only an inquiry into cause, but an investigation of the whole empire of Nature and a determination of the applicability of every species of knowledge to the improvement of his art.

Two public monuments have been erected to his memory: one at Apalachicola, Florida, the other, a statue in Statuary Hall of the Capitol of the United States. The Florida monument, the gift of the Southern Ice Exchange, was unveiled on April 30, 1900. It is a large urn or vase draped with a veil, made of white bronze, which rests on a pedestal whose four paneled sides bear inscriptions of greatest significance in the life of Dr. Gorrie. The statue in Statuary Hall of the Capitol of the United States was placed there through the Act of Congress of July 17, 1864, which allowed "statues of two distinguished citizens from each state who were illustrious for their historic renown"; and the joint resolution of Congress of February 6, 1914.

The statue was unveiled in Statuary Hall on April 10, 1914, and is the work of the sculptor, C. Adrian Pillars, of Jacksonville, Florida, one of the sculptors of the figures for the Columbian Exposition of 1893. Fig. 3 is a reproduction of the statue as it appears in Statuary Hall to-day [7a]

The state of Florida and its citizenry, medical and lay, have recently established two new memorials to his memory. About a year ago the John Gorrie Memorial Foundation was chartered in Florida to provide hospitalization in Apalachicola and to carry on a nation-wide drive against cancer. More recently, the governor of Florida proclaimed August 11–17 as the "Dr. John Gorrie Ice Memorial Week," which is a plan by which the ice industry gives one day's receipts each year to the Memorial Foundation.

If Dr Gorrie had not possessed the inventive type of mind, it is extremely doubtful that he would have been thus memorialized, even though it can truly be said that as a physician he was one who was outstanding in the field of scientific medicine.

One of his professional friends and neighbor, the celebrated botanist physician, Dr. Alvan Wentworth Chapman, who settled in Apalachicola in 1847, said to Dr. Asa Gray, the noted botanist of Harvard, when the two passed by Dr. Gorrie's grave, "Gray, there is the grave of the man whom we all recognize as the superior of all of us."[8]

The editor of the *New Orleans Medical and Surgical Journal,* in an obituary notice, likewise regarded Dr. Gorrie as the "distinguished physician and scientist," an "acute thinker" and a "classical writer."[9]

His local lay friends expressed their devotion and regard at his death. It is said that "For two days there was a throng viewing the remains at his home, and the funeral cortege was the largest ever seen in Apalachicola."[10]

[7a] Figures 1 and 2 were kindly furnished by the Smithsonian Institution of Washington, through the courtesy of Mr. Frank Taylor, curator, Division of Engineering; Figure 3, by Mr. David Lynn, architect of the Capitol, Washington, D. C.

[8] *Ice and Refrigeration,* 18: 491, 1900.

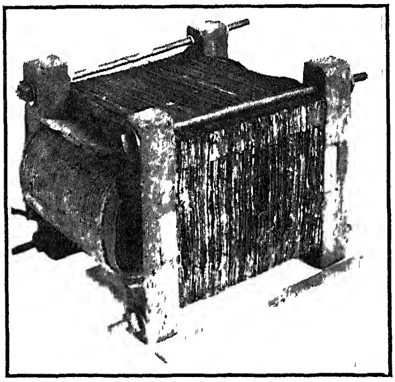
[9] *New Orleans Medical and Surgical Journal,* 12: 288, 1855–56.

[10] *Ice and Refrigeration,* 12: 351, 1897.

THE PROGRESS OF SCIENCE

THE FIFTIETH ANNIVERSARY OF ALTERNATING CURRENT

THE March floods solved a problem and staged a demonstration. When plans for celebrating the fiftieth anniversary of the alternating current in America on March 20 were being made by the American Institute of Electrical Engineers some six months ago, it was proposed that the programs in two score cities should not only recount its early history but should feature also its development and its significance in the life of today. The problem was how to impress people by what has become commonplace although it may once have been wonderful. It is sometimes as impossible to realize conditions fifty years ago as it would have been for grandfather to see any sense in the story of a Utopia with flying machines and radio.



TYPE OF TRANSFORMER
USED IN GREAT BARRINGTON DEMONSTRATION FIFTY YEARS AGO.

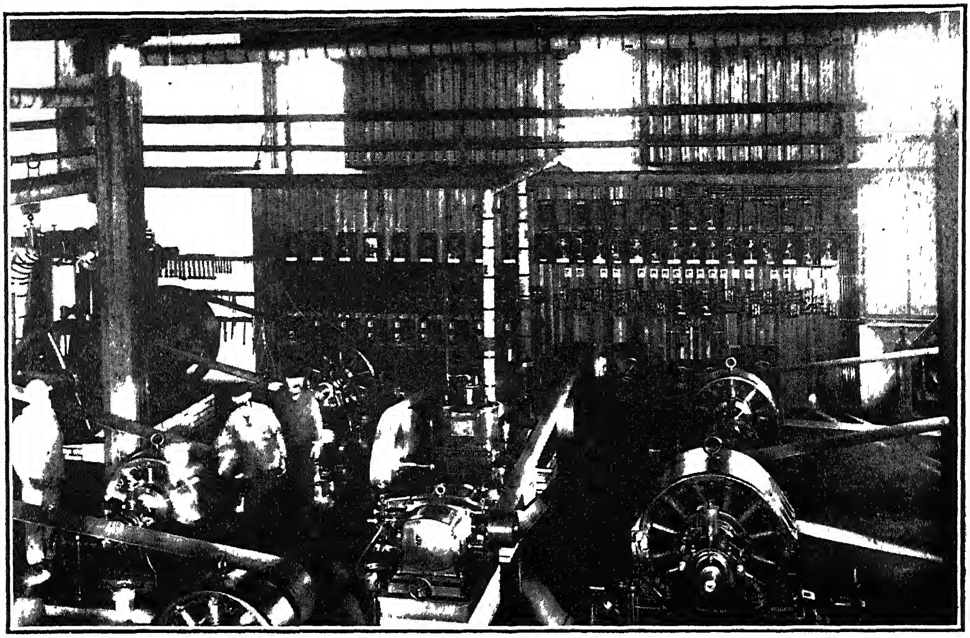
But a few days before the twentieth there came unprecedented floods; in Pittsburgh four feet of water in the hotel banquet room cancelled the local anniversary program. The crowning catastrophe was the submergence of the electric power stations, cutting off electric service. The significance of electric power in our daily life was tragically demonstrated

On the evening of the eighteenth, I left Pittsburgh (a Venice with dark canal-streets bordered by dark skyscrapers) on a suburban train and presently walked up a dark street to the simple residence where I was staying. Soon I realized the function of electricity in the home by its absence. There are tabulated in the table actual cessations in that ordinary home—light and power, heat and cold, sound and time; fortunately the furnace had no electric regulator or stoker and the range was fed with gas. Outside the house one realized a cessation of street cars, street lights, newspaper presses, gasolene pumps and building elevators The emergencies in home life become calamities in hospitals, public service, commercial buildings and industries

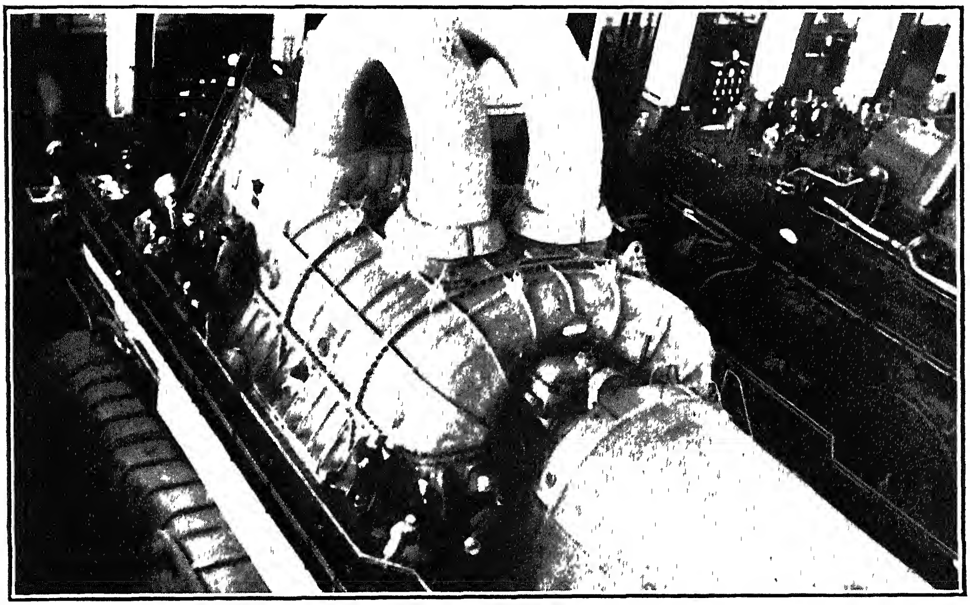
And thus we realize that we are living in the age of electric power. What is it? Whence came it? Power and electricity—the two in a sort of combination Power—other than muscle power—came into common use with Watt's steam-engine, invented about the time of the

A SUBURBAN HOME LOSES ITS ELECTRIC CURRENT

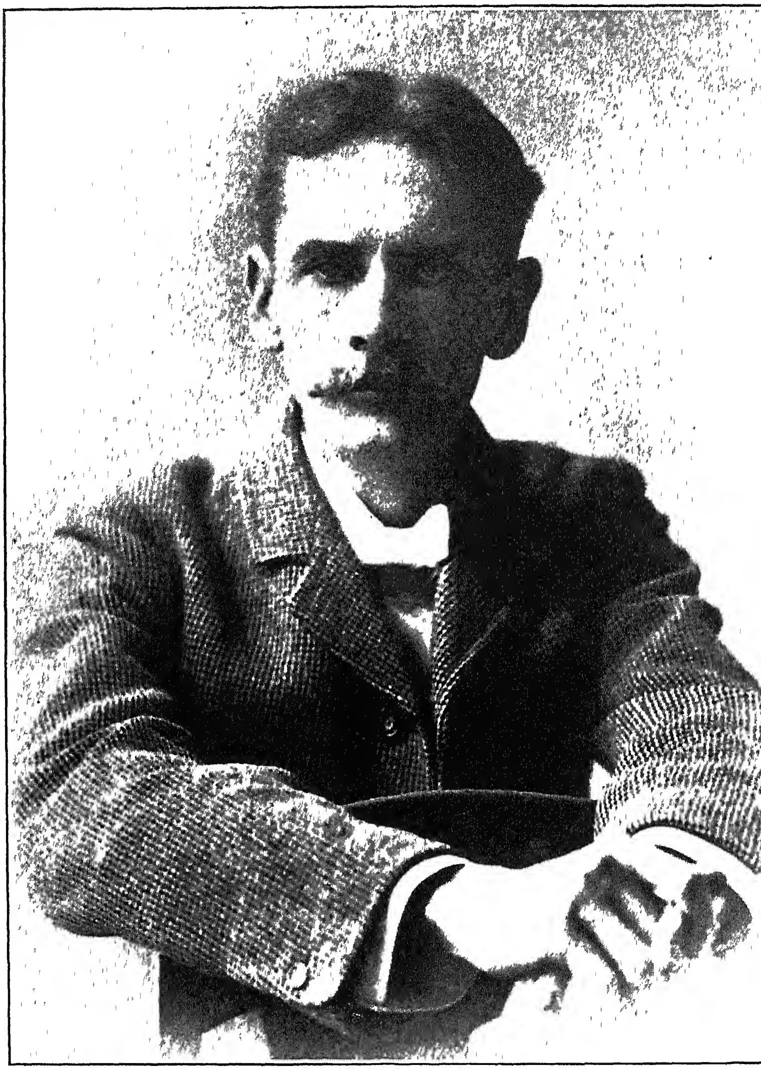
What stopped	Old-time methods
Electric lights	Candles
" sweeper	Broom
" washer	Wash-board
" toaster	Stove
" iron	Flat-iron, stove
" pad	Hot brick
" refrigerator	Ice
" door bell	Knocker
" radio	————
" clock	Grandfather's clock
Telephone (no current)	————
Water (no electric pumping)	Well and cistern



AN EARLY ALTERNATING CURRENT CENTRAL STATION
WITH SEVERAL BELT-DRIVEN ALTERNATORS. TOTAL CAPACITY, ABOUT 200 K. W.



TURBINE GENERATOR IN PHILADELPHIA
LARGEST OF ITS KIND (165 K W.) BUILT BY WESTINGHOUSE.



WILLIAM STANLEY

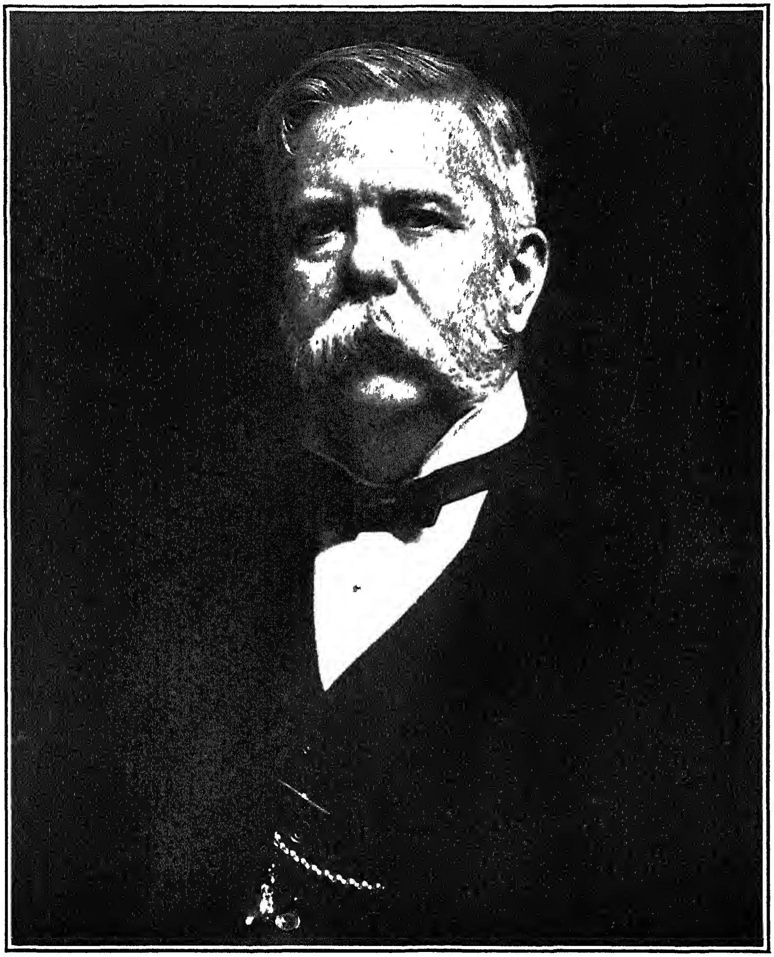
ELECTRICAL ENGINEER WHOSE PIONEER PLANT AT GREAT BARRINGTON, MASS., INAUGURATED THE ALTERNATING CURRENT SYSTEM IN THE UNITED STATES.

Declaration of Independence. After a century it was running steamboats and railway trains and factory machinery through shafting and belts Electricity is thousands of years old—the frictional kind that Benjamin Franklin said gave no promise of being of use to mankind. Then came batteries in 1800, followed by the telegraph, electro plating and the telephone; also scientific studies which through Faraday and his followers eventuated in the dynamo. Expensive battery current has been replaced by cheap dynamo current as the driving power is steam or falling water. Thus mechanical power now becomes electric power which can be transmitted far beyond the range of belts and shafts and can be converted into motor power or light or heat or used for chemical pur-

poses. Thus electricity amplifies the usefulness of power.

At the Centennial in 1876 Professor Elihu Thomson got a thrill which shaped his career from "a dynamo which ran one arc lamp" Within the next half dozen years there came arc lighting for streets, and incandescent lighting for interiors—thanks to Edison's lamp and system From his Pearl Street (New York City) station in 1882 came electric energy as a commercial commodity. But a half mile or so was the limit, beyond which the cost of conductors became excessive

George Westinghouse, having established the air brake, sought new activities. The electrical field was attractive. He secured William Stanley, electrical inventor, who developed direct current appliances for incandescent lighting which Westinghouse manufactured But the few thousand feet which limited the commercial radius made the prospect uninviting. He learned of a foreign system employing alternating current with high pressure for transmission over long distances and a "secondary generator" (transformer) for reducing the pressure for use This was analogous to his own



GEORGE WESTINGHOUSE,
SPONSOR OF THE ALTERNATING CURRENT.

system for transmitting natural gas at high pressure with reducing valves for adapting it for service. He at once acquired rights and apparatus; Stanley as electrical expert proposed changes based on electrical features—counter electromotive force, magnetic circuit, windings and circuit connections Westinghouse, mechanical expert, proposed reconstruction so that the coils could be wound in a lathe A new company was formed and arrangements made for a demonstration plant to be built by Stanley at Great Barrington Generators and transformers from the Pittsburgh factory were supplemented by transformers made at Great Barrington The plant began service on March 20, 1886, supplying a score of houses and stores with incandescent lamps for three months Its success was followed by commercial plants, beginning at Buffalo on Thanksgiving Day, 1886.

The service was incandescent lighting and its merit was its suitability for long distance transmission

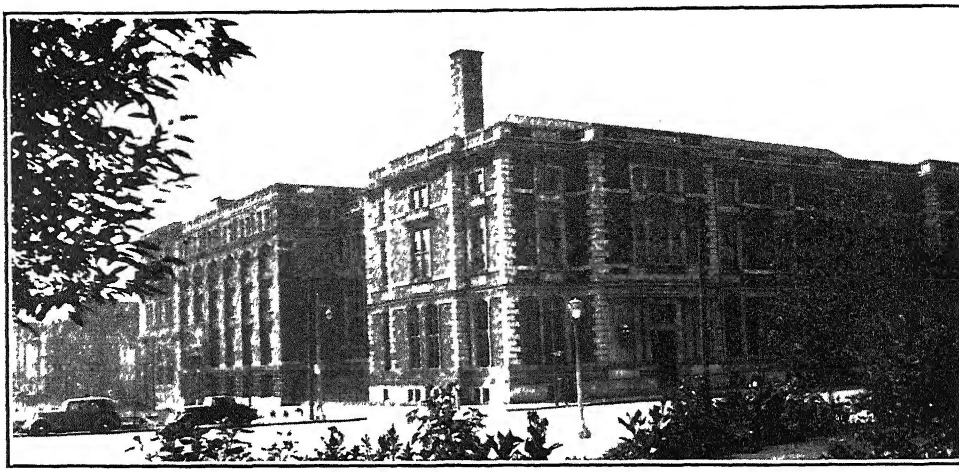
Next came the Tesla polyphase system. Its mechanical analogue is a two-crank or a three-crank instead of a single-crank ("single phase") engine This system operates induction and synchronous motors and is adapted for supplying all electric services from one source. Formerly arc lighting, incandescent lighting and street railways required different kinds of generators and independent circuits Furthermore, the largest direct circuit generating units are structurally limited to five or ten thousand kilowatts, while alternators are made for twenty times that output. Thus the new alternating system is suited to large units, to transmission, to conversion into various forms suited to the universal service which it now renders It was demonstrated at the Chicago World's Fair in 1893 and commercially inaugurated at Niagara in 1895

The simple beginnings of fifty years ago were followed by scientific research, engineering development of apparatus, manufacturing facilities, power stations and transmission systems, motors and appliances—all these providing the physical equipment. These have involved the creation of new industries with new fields of employment Remote water powers have become national assets involving new questions of governmental policy and constitutional interpretation The new uses of power ramify our industrial, commercial and social life. Herbert Hoover said "Electricity is the greatest tool that ever came into the hands of man", and we celebrate the beginning of the transformer which contributed to make it so.

CHARLES F SCOTT

THE NATURAL HISTORY MUSEUM AT PHILADELPHIA

A PROGRAM which will make the Academy of Natural Sciences of Philadelphia an active part of that city's educational system was announced by Effingham B. Morris, president of this institution, the oldest of its kind in America, at the recent opening of the new East African water-hole habitat group in African Hall in the academy's museum Dr James Bryant Conant, president of Harvard University, and Dr. William Berryman Scott, emeritus professor of geology at Princeton University, who spoke at the large gathering of academy members and guests, urged the carrying out of this program, which embodies extensive additions to and rearrangement of present exhibits in the academy's Free Natural History Museum; active cooperation with public and private schools in and near Philadelphia in the study of natural history subjects, and the reestablishment of the academy's department of paleontology. The latter will continue the study of the history of life through its priceless collections of fossil remains of past geological periods and thus accomplish the first step in meeting the



THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA

growing demands of nearby centers of higher education for cooperation in all fields of scientific research.

From its founding in 1812 and until 1929 the academy continued to grow in scientific importance, but the public was not kept in touch with its development. It could not be expected that such a man as Joseph Leidy, one of the greatest naturalists who ever lived and father of vertebrate paleontology in America, should take the time from his life's work to build popular exhibits for the edification of a public uninformed in the fundamentals of his subject.

He served the public, but in a larger sense. He built up his branch of the natural sciences so that to-day all the great oil companies of the world owe him a debt of gratitude as well as the coal consumers of every household. For it is often owing to the efforts of the research scientist who labored in a field where at first there seemed no "practical" advantage that mankind has ultimately benefitted from science.

In 1929 the picture began to change. New trustees, a new president, and a new managing director found a new interest and understanding on the part of the public. They knew that the life of the institution lay with its men, but they also found that the average American was demanding an increasing service from its scientific institutions—that the public, as well as the scientist, was turning more and more to the academy for what it could give. Steps were taken accordingly, and in the last six years the visitor to the academy has found an attendance increased seven-fold; classes of school children viewing the exhibits; new specimens brought back from more than 130 scientific expeditions to the remote places of the six continents; a museum changed from what formerly must have seemed an old curio shop to one with more meaning; notable life groups of animals in their native habitats reproduced in detail, accurate to the smallest blade of grass.

Recognizing museum exhibits as the open door to an awakening of interest in the fascinations of natural history, the trustees of the academy have decided that a study should be made to show just how its free museum should be arranged and what it should do. Despite great advances, the possibilities in museum planning are just beginning to be realized. It is the determination of the trustees that the academy shall contribute to the advancement of this essential service to the public.

JOSEPH LEIDY
—A RARE PHOTOGRAPH MADE ABOUT 1858, ALSO SHOWING ONE OF THE BONES OF THE HADROSAURUS FOULKII, THE SKELETON OF WHICH WAS UNEARTHED IN THAT YEAR NEAR HADDONFIELD, N J LEIDY, WHO THEN WAS DOING BRILLIANT WORK AT THE ACADEMY OF NATURAL SCIENCES, OF WHICH HE LATER BECAME PRESIDENT, DESCRIBED THIS FOSSIL LIZARD, WHICH WAS THE FIRST DINOSAUR TO BE FOUND IN THE EASTERN UNITED STATES A RESTORATION MADE BY B. WATERHOUSE HAWKINS, OF LONDON, STILL IS ON EXHIBIT IN THE ACADEMY'S FREE NATURAL HISTORY MUSEUM.

Closely related to museum planning, but, nevertheless, a field of its own, is the development of an active program of education in cooperation with the Philadelphia public and with grade and private schools The start already made, which last year brought more than 30,000 school children to the academy, some coming from such relatively distant points as Atlantic City and Reading, and 150,000 adults, has only given evidence of the need. The merits of arousing the child's interest in science are recognized to-day by ever-increasing numbers. The importance of the natural science particularly can not be overstated, since an interest in natural history takes the child out of doors and brings a healthy and wholesome influence into his or her life.

In that great branch of the natural sciences where the study of the earth and the study of the life upon it meet, that of the fossil remains of ancient life as revealed in the rocks, or technically the division of geology known as paleontology, the Academy of Natural Sciences has a proud tradition. In the work of men like Leidy and Cope, two of the academy's greatest scientists, there is a unique heritage. It is the determination of the trustees to reestablish this department, to bring to the academy's staff an able scientist, and to put in order the priceless collections which are now unavailable for study

Increasing recognition is to-day being given to the vital need for closer cooperation of the college and university with the research center. There can be no questioning the fact that graduate students and professors alike can benefit greatly from a closer relationship with institutions like the academy which have great collections and skilled research scientists. The academy has the opportunity of building, without fear of duplication—indeed, to fill a great gap—a department of paleontology designed particularly with a view to meeting the demand for cooperating with nearby institutions of higher education.

These are the first three steps Because they have been undertaken first does not mean that the other activities of the academy will be neglected. It is admitted that there are pressing demands upon the services of the library, the department of publications, and that there is a definite need for more staff and equipment for all phases of the institution's scientific work These needs will be studied also.

L. M. H.

ISLE ROYALE AS A NATIONAL PARK

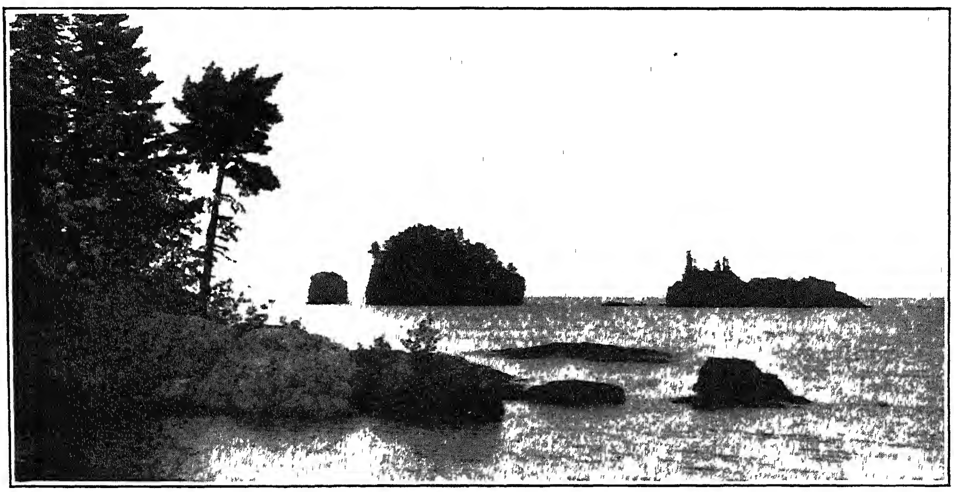
Announcement that Isle Royale, island wilderness far out in Lake Superior, may soon become a national park is of especial interest to the naturalist, botanist and ethnologist. This hitherto secluded area, up to now absolutely unspoiled, has been in the public eye of late because of rumors that the virgin timber with which the island is covered was about to be logged Michigan, Wisconsin and Minnesota conservationists have organized the Isle Royale National Park Association, with offices in Escanaba, Michigan, to further by all means in their power the early consummation of plans to convert the entire area into a national park, which will become at the same time a primeval forest preserve and a sanctuary for the largest herd of moose on the continent.

Isle Royale[1] lies about forty-five miles north and west of Keweenaw Point, which is the northernmost locality on the Michigan mainland. The island occupies a northeast and southwest position fourteen miles from the nearest Canadian shore. It is forty-four miles long and from three to nine miles wide, with an approximate area of 205 square miles, of which twelve square miles are occupied by more than twenty-five lakes. Hundreds of rocky islets surround the main islands, forming an archipelago with a total length of fifty-seven miles. The island is the largest in the Great Lakes owned by the United States

The geological formation of Isle Royale consists of a series of upturned lava flows, striking southwest and with a dip to the southeast The strata of lava disappear with the lake and make their reappearance on the south side of the latter, where they emerge to form Keweenaw Point The truncated ends of these ancient lava flows form long ridges ranging from one hundred to five hundred feet in height.

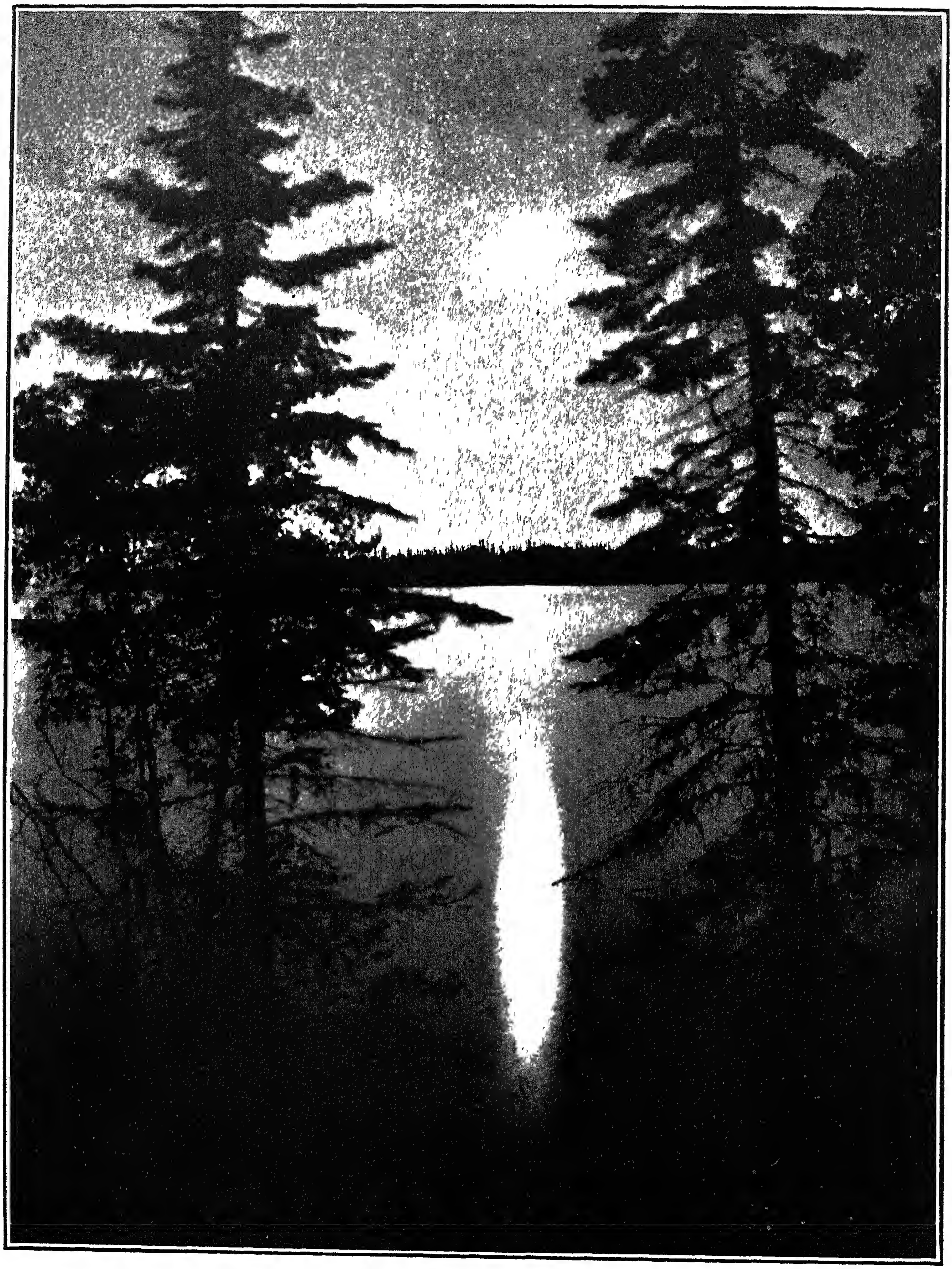
Glacial action has removed the softer strata, but enough of the latter have remained to provide sustenance for at least twenty-one species of trees, of which thirteen are deciduous and the balance evergreens. As a whole the

[1] The photographs have been loaned to the author by the Superior Art Company of Houghton, Michigan



ROCKS OFF THE MAIN ISLAND

Isle Royale and its more than 1,000 islets were hurled ages ago from the mouth of some long-extinct volcano. The fantastic lava formations extend over 50 miles, and are covered for much of the distance by primeval forests untouched by ax or fire.



MOONLIGHT AT ISLE ROYALE

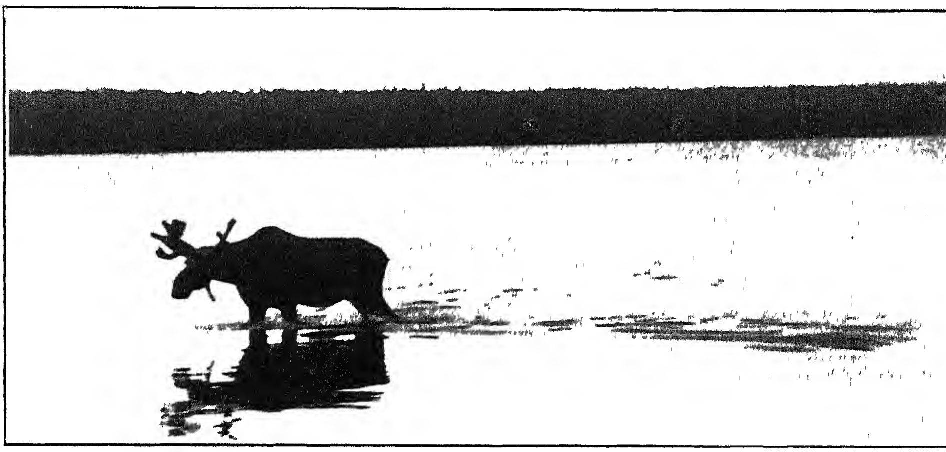
island is heavily timbered with trees that have never been cut and are little harmed by the ravages of fire. The dominant species are the balsam fir, the white or canoe birch and the black or cherry birch, as well as the hard maples and some oaks

The birds on the island are those of the mainland on both sides of the lake, including many of a sub-arctic type The animals include most of the species of sub-arctic Canada and northern Michigan, including moose, woodland caribou, the Canadian lynx and the timber wolf Isle Royale is said to be the only home of the woodland caribou in the United States.

The moose herd is probably the largest single herd in North America. The increase of the moose on the island is of comparatively recent occurrence. Twenty years ago they were scarcely to be found there At present there are probably 450 to 500 moose on Isle Royale, and a limited number were removed recently by the Michigan Department of Conservation to the northern mainland counties because of a growing food shortage. The transference of animals will probably continue, and meanwhile the food situation is being carefully studied by department mammalogists.

While the moose are one of the largest animals in the western hemisphere, they are quite harmless, and individuals occasionally wander into the hotel premises on the island Because of its exceptionally pure and dustless air the locality has been for years a haven for people of the central west who are suffering from hay fever, and a large part of the summer hotel patronage is composed of hay fever and asthma patients The four hotels operate from June 25 to the close of the hay fever season, and their combined capacity is about four hundred.

The north and south shores of the island are liberally dotted with copper mining pits made by some prehistoric race whose identity remains a mystery The characteristically pure native copper of Isle Royale is found in many burial and other mounds in the southern states and Mexico, yet no copper was in use by the Indian tribes when America was discovered. Archeologists and ethnologists have made numerous expeditions to the island in endeavors to trace the unknown miners, and other excursions of the kind are in prospect for this year. It has been found that trees over four hundred years old are growing in some of the pits, but no one knows how much older the latter may be. The excavations represent a



MOOSE ON ISLE ROYALE

volume of toil comparable to that exercised in the building of the great pyramids of Egypt, and the quantity of copper recovered must have totaled hundreds of tons.

Couple these factors with the undeniably good fishing on and around the island, the average summer temperature of 64 degrees and the fact that no roads other than moose trails exist from one end of the terrain to the other, and it will be recognized that Isle Royale as a national park will be unique and very different from any other park in the national chain. The island lies within a day's run or a night's journey of many millions of people, and its accessibility is now beyond question.

Harvesting operations of Isle Royale timber must be prevented at all hazards. Logging there will not only scar a landscape of aboriginal loveliness but create a fire hazard which may do untold damage requiring centuries to repair, and destroy the home of the moose that are now so great an attraction. The move, therefore, to keep Isle Royale precisely as it is is in line with the soundest ideals of practical conservation—ideals which are touching a responsive chord in the soul of America. The proponents of the park plan for Isle Royale have been heartened indeed by the stirring response to their appeal for cooperation.

W. D.

EXPERIMENTAL BIOLOGY AT THE WASHINGTON MEETINGS

The Federation of American Societies for Experimental Biology, which convened in Washington for four days at the end of March, is composed of four societies having a common interest. They are the American Physiological Society, the American Society of Biological Chemists, Inc., the American Society for Pharmacology and the American Society for Experimental Pathology. A large proportion of the members of the American Institute of Nutrition are also members of one or more of the societies in the federation and it met with the larger group.

The extent and interest in experimental work in the past year is indicated by the fact that in four days approximately 1,700 scientists listened to one or more of 470 papers and saw forty demonstrations; ninety-three papers were read by title. Eleven formal sessions were held simultaneously. In addition there were countless conversations outside the meeting rooms, conversations that are often the most stimulating part of a convention. The following annotations indicate some of the results reported at the meetings:

As a result of relief measures, the depression did not adversely affect the nutritional status of the average individual in the United States. In fact, the poor were often better fed than formerly. The greatest hardship fell on those who changed from a relatively comfortable to a poor economic state. The ordinary heating of protein, such as meat or milk, does not affect its nutritive value, provided the digestibility of the food is not lowered. Growing children show a variable and often a step-wise retention of protein. Experiments indicate that care should be taken to see that the diets of children contain adequate amounts of Vitamin A or carotene, and the Vitamin B complex Vitamin G, present in many foods, especially meat, milk, eggs, wheat germ and many vegetables, is a factor, along with Vitamin A, in good eyesight. Cataracts often accompany retarded growth when Vitamin G is lacking in the body. Flavins, pigments in eggs, liver and milk and other foods affect growth. They stimulate the appetite. There are at least two antirachitic vitamins (Vitamins D). Both vitamins are obtained by irradiation

with ultra-violet light. The one in fish oils is most efficient with children The other, obtained from cholesterol, is more effective with poultry.

Certain amino acids, the fundamental constituents of protein, can not be made by animals, and must be obtained from food The search for a mixture of amino acids that will support life led to the discovery, reported last year, of a new amino acid hitherto unrecognized as essential It was l-α-amino-d-β-hydroxy-n-butyric acid, and has now been named threonine A sulfur containing amino acid, methionine, has been found to be essential Whether or not methionine can completely replace cystine, formerly held to be essential, remains to be shown. The essential amino acids at present known are lysine, tryptophan, histidine, phenylalanine, valine, leucine isoleucine, methionine, hydroxy-amino butyric acid, (cystine ?).

The early water soluble Vitamin B was once supposed to be a single substance Now it is sometimes called "Vitamin B Complex" Six Vitamins B have been suggested, plus two other factors, one known as flavin, and the other as the pellagra preventive factor for man. Some of these factors may be duplications. Other members or manifestations of the B complex were described at the meetings, such as a factor which prevents characteristic lesions in chicken gizzards, another factor which prevents severe skin diseases in rats and chickens, also necessary for growth, and a new vitamin H.

Hormones and their effects were discussed at nearly every session of the meeting. A new hormone, lipociac hormone, was described, which apparently controls the utilization of fat in the body. Evidence of a new hormone in the adrenal gland, in addition to adrenaline and cortin, was presented. This hormone appears to control the decrease in size of the thymus gland. This gland has a relation to early growth and development. It normally decreases in size during childhood. Evidence that the thymus gland influences the growth and development of young was presented. Injections of the thymus gland were injected into successive generations of male and female rats Up to the twelfth generation, the young of each succeeding generation showed a greater rate of growth and maturity than the preceding generation. Extracts of the pineal gland, in the brain, showed the opposite effect. There was an accruing retardation in the rate of growth, accompanied by an accruing development of the young The presence of a fourth hormone in the adrenal gland, cortipressin, was suggested. This hormone appears to be effective in raising the blood pressure.

The specific effects of hormones on particular processes are steps in understanding body function. Life is not a series of isolated activities, but the interaction of all processes. The pituitary gland in the skull appears to be a regulating center of hormone activity. The pituitary was shown to play a part in keeping a balance between the liberation of sugar, probably in the liver, and the secretion of insulin needed in the utilization of sugar. The pituitary was also shown to influence the production of the hormone of the adrenals, mentioned above, affecting the involution of the thymus. The activity of the pituitary gland is affected by disturbances in the body. One such evidence was given in the demonstration that when the nerve supply between a small nerve center, the supra-optic center, in the brain to the pituitary gland is severed, an excessive loss of water occurs through the kidneys. The ultimate effect is believed to be due to the action of a pituitary hormone on the kidneys.

Study of the brain and nervous system has shown that consciousness or unconsciousness may depend upon an electrical state of the brain. When the electrical potential of the cerebral cortex is

higher than that of the rest of the nervous system, the animal is "conscious" When it is lower, "unconsciousness" results. The suggestion was made that electrical response is basic to hearing. The transmission of sound begins with certain fine, hair-capped cells in the inner ear Loss of hearing is accompanied by the total or partial destruction of these cells There is a "safety factor" in hearing Both sides of the brain can detect impulses from the sound-receiving organ in either ear

The depth of sleep varies during the night Every one moves more or less when sleeping. After a movement the depth of sleep gradually increases to gradually decrease again as the time for another movement approaches. Sleep is deeper the longer the time between movements. The knee jerk may be a useful test of "physical fitness." An increase in physical or mental work, with accompanying fatigue, required a heavier blow on the knee to cause a response than after rest. The lightest blow was required upon arising in the morning. Recovery from fatigue was more rapid in the "physically fit." The time required for a human stomach to empty after a meal increased with the altitude. Fifty per cent more time is required to empty a stomach at Pike's Peak than at sea level The beating of the hearts of dogs could be restored five to seven minutes after the heart had entered the state of fibrillation, which precedes complete stopping, through the application of an alternating electrical current. If the heart is massaged just before applying the shock, the expectancy for revival could be tripled or quadrupled. When the fore legs of salamanders were interchanged by a surgical operation, the legs continued to move in the direction in which they were accustomed, that is, backward when the animal was trying to go forward

Alcohol was shown to increase the deposition of fat in the liver, even on a diet which produces fatty livers. That the toxemia of pregnancy may be hereditary was indicated by experiments on rabbits. The disease studied is a disorder of carbohydrate and fat metabolism The association with pregnancy is due to the metabolic activity of the mother, rather than to the specific effect of the developing young Removal of the ovaries from female mice resulted in marked decrease in the incidence of cancer of the mammary gland to which that particular strain was susceptible If the ovaries were removed early in life, cancer did not develop On the other hand, if the removal was delayed until the mice were eight or nine months old, removal of the ovaries was ineffective Large doses of the female hormone from the ovaries into male or female mice increased the incidence of cancer.

A new internal antiseptic, phenthiazine, that shows great promise if properly used, has been found as a result of studies on the toxicity of this substance in connection with investigations of insecticides for fruits and vegetables. Caffein, the nerve-stimulating alkaloid of the coffee bean, decreases reaction time (increases speed) and the accuracy of a simple hand movement test Taken in the form of coffee, however, its effect is only about half as great. Deuterium, or heavy hydrogen, given in the form of heavy water, was employed to tag water used in the synthesis of fatty acids in the body. The data indicated that there is a continual synthesis and utilization of fats in the body.

Paul E. Howe

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SOME RELATIONS OF THE NEW HARMONY MOVEMENT TO THE HISTORY OF SCIENCE IN AMERICA

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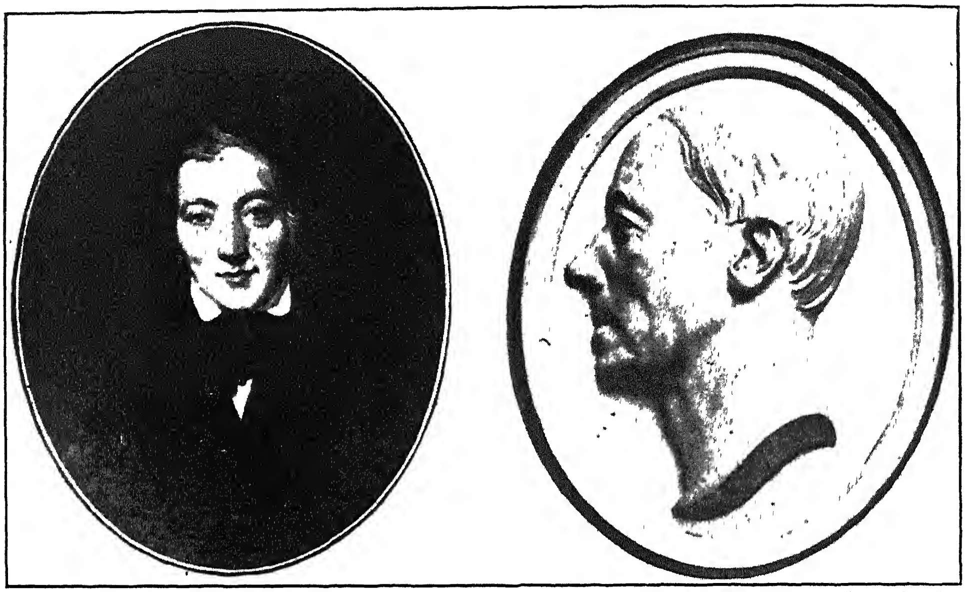
THE widening of the scientific frontiers in the English-speaking settlements of North America is indicated by a number of definite landmarks which offer to the historian convenient starting points from which to explore the intellectual development of various regions. The establishment of a laboratory in Boston by the younger Winthrop three centuries ago is one of these landmarks, for it was he who gave the first impetus to scientific studies in the English colonies. The founding of a laboratory by the exiled Priestley in 1794 at Northumberland, Pennsylvania, then upon the borders of the western wilderness, is another of these scientific outposts which helped to enlarge the intellectual boundaries of the young American republic. A third example was the establishment by Robert Owen in 1825 of a communistic colony at New Harmony, Indiana, from which center a group of eminent men set forth during the next half century to assist in the scientific development of the Middle West.

Robert Owen, the founder of English socialism, deserves the credit of having made the first and only actual experiment in America of applying the theories of communism to a society in which science occupied a leading position. This was not a new conception. Among the literary works of various epochs, which describe an ideal society of humankind, are several that picture the man of science as the proper helmsman of affairs. In Plato's "Republic," the earliest and greatest of these imaginative conceptions in which many of the social panaceas of later writers are anticipated, it will be recalled that the legislators of his ideal community must first have perfected themselves in the mathematical sciences, by which was meant the Pythagorean quadrivium of arithmetic, geometry, astronomy and music. These belonged to the ancient liberal arts, as contrasted with the so-called practical arts, such as agriculture, architecture, navigation and metallurgy, the study of which Plato held to be unworthy of serious attention. Yet Plato realized very clearly that his οἰκισταί, or legislators, must humanize their scientific knowledge by descending from their ivory towers and mingling with the common herd. "They must not be permitted," says Socrates in Plato's dialogue, "to remain in the upper world as philosophers do now but be made to descend among the prisoners in bondage and share their labors and honors whether these be more sordid or more worthy." But Glaucon asks, "Is it just



National Portrait Gallery, London

FIG. 1. ROBERT OWEN (1771–1858)

PORTRAIT BY W H. BROOKE IN 1834. MEDALLION BY JULIAN LEVEROTTE.

to dishonor them and make them lead an inferior life when they could have a superior one?" "You forget," Socrates replied, "the purpose of the law, which was not that one class of the community should fare happier than the rest but that all should be made happy alike"

This ideal of bringing equal happiness to the members of a community through the agency of science was cherished again twenty centuries later than Plato by Sir Francis Bacon in his "New Atlantis," where a bureau of investigators, working cooperatively, was supposed to increase the well-being of their fellowmen by means of their discoveries and inventions. Bacon for the first time stressed the importance to the community of training citizens in the neglected industrial arts, such as those of the farm, the kitchen and machine shop.

The practical application of some of these Utopian schemes did not begin to be seriously considered until after the outbreak of the American Revolution, which acted as a stimulus to the minds of social as well as of political reformers. Saint Simon (1760–1825) and Fourier (1772–1837) in France and Robert Owen (1771–1858) in England all attempted to found communistic societies and all with the same inevitable failure. Saint Simon advocated a new industrial state under the direction of men of science, a socialistic scheme which has had its latest repercussion in the recent flare-up of technocracy. Many young graduates of the École Polytechnique, afterwards famous as engineers, economists and practical business men, were attracted to the Saint Simon colony, in the Rue Monsigny of Paris, which supported itself for a brief period out of a common purse and then was dissolved.

These communistic experiments found their richest field for development in the United States, where over 50 different socialistic colonies were founded before 1850. The oldest of these, established by the Shakers at Watervliet, New Yor, in 1776, was of a strictly religious character, and it may be noted in passing that in its few remaining centers the self-supporting colonies of the Shakers have been the longest to survive.

Another of these sectarian communis-

tic groups was that of the Rappites, a company of pious German peasants from Württemberg, who, under their religious leader, George Rapp, settled first in 1804 near Zelienople, Pennsylvania, and then in 1815, desiring a more favorable situation, established a second colony in Indiana to which they gave the name of Harmony Here this society of primitive Christians, or Harmonists, erected numerous log, frame, stone and brick buildings, among which were a large church, a granary, numerous residences, 6 large community houses and 8 or 10 small factories. Some 3,000 acres of land were laid out in farms with vineyards and orchards. This settlement in the wilderness was soon transformed by the industry of its inhabitants, about 1,000 in number, into a beautiful agricultural community, which became one of the early show places of the Middle West. To quote an early observer. "It would seem to the traveled visitor like some quaint German village, transported from the Neckar, or the Rhine, and set down in this western waste like an Aladdin's palace " After ten years of prosperity, during which the Rappite property was said to have increased in value to over $1,000,000, its leader, always restless for new adventures, decided to move back again to Pennsylvania, and the whole tract of Harmony with land, buildings and equipments was sold in 1825 to Robert Owen, as the site of a new communistic experiment, for less than $150,000.[1]

Robert Owen, the purchaser of Harmony, had ideas of social reform that were wholly unlike those held by its original founder. Instead of a religious autocracy, it was Owen's purpose to found a different type of community, a New Harmony, in which all the inhabitants would be people of superior intelligence and education, all striving amicably together toward his own ideals of high social attainment. Certainly, no

[1] With the proceeds of this sale Rapp purchased a large estate in Beaver County, Pennsylvania, eighteen miles below Pittsburgh on the Ohio River, and there his colony of obedient followers with renewed labor created another communistic settlement called Economy, which continued to exist with diminishing success until after the beginning of the present century, when decreasing numbers brought its activities to an end.

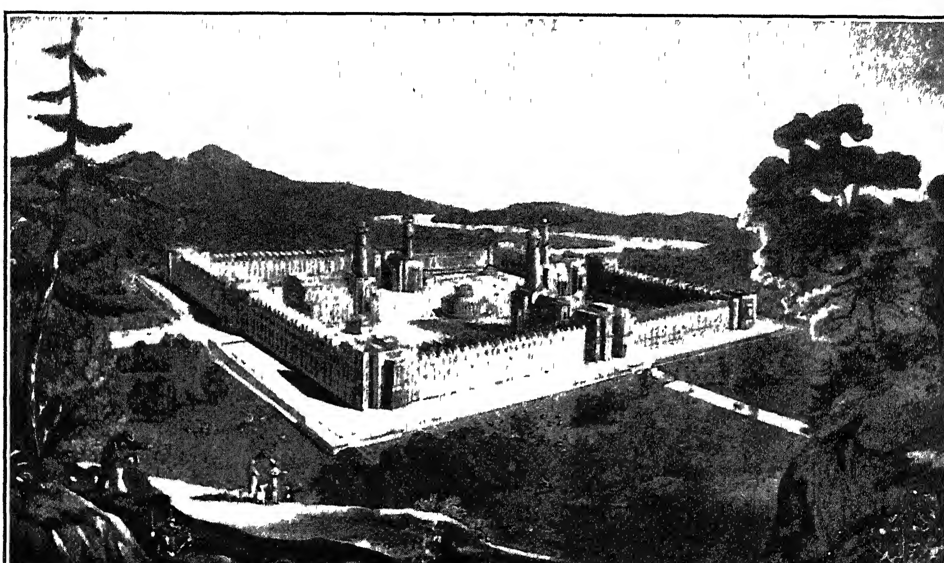


FIG 2. ROBERT OWEN'S PROPOSED COMMUNITY VILLAGE
FROM AN OLD PRINT

FIG 3 WILLIAM MACLURE (1763–1840)
PORTRAIT IN AMERICAN JOURNAL OF SCIENCE, OCTOBER, 1844.

one was better qualified than Owen, in character, training and ability, to head such a movement. At a time when labor-saving machinery first began to be employed on an extensive scale, Owen by his high administrative and technical ability became at the early age of 19 the

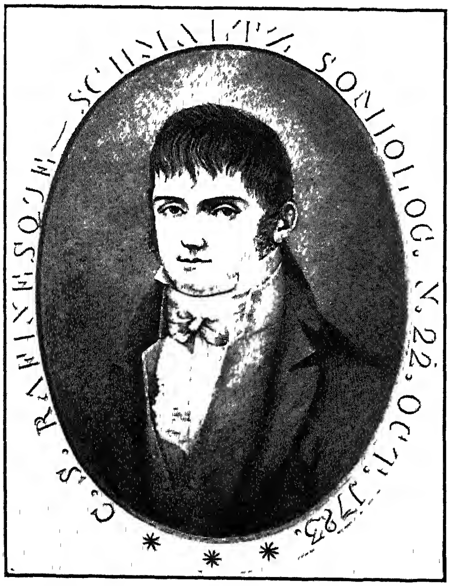


FIG. 4. CONSTANTINE SAMUEL RAFINESQUE (1783–1840)
FROM AN ENGRAVING IN RAFINESQUE'S "ANALYSE DE LA NATURE."

superintendent of a large cotton mill in Manchester and with such success that he soon made it one of the leading factories in Great Britain. Shortly after this he married the daughter of a wealthy manufacturer at New Lanark, Scotland, in whose factory he acquired by purchase a controlling share. As manager of this factory he took a most active philanthropic interest in improving the living conditions of the workmen of his mills. By the betterment of homes and of sanitation, by reducing the drudgery of labor, by encouraging habits of thrift and of temperance and by the establishment of model schools, he effected such an uplift in the character of the community that New Lanark was visited by royalty, social reformers and statesmen from all parts of Europe.

After the great business depression in Great Britain which followed the Napoleonic wars, Owen came to the conclusion that the competition of human labor with machinery was the great cause of the difficulty and that the only cure of existing evils was a reorganization of society in which machinery should be subordinated to man. For this purpose he advocated the establishment of self-supporting agricultural-industrial settlements of about 1,200 persons, each with from 1,000 to 1,500 acres of land Each community was to be supervised by capable, scientifically trained overseers; complete facilities for public education were to be supplied, private ownership of property was to be abolished and the rewards of labor were to be shared in common. Having failed in his efforts to establish such settlements in Great Britain, he came to America, where at the opportune moment the community of the Rappites at Harmony, which seemed ideal for a first experiment, was offered for sale and purchased.

What Owen hoped to accomplish by his proposed regeneration of society was indicated in two memorable addresses which he delivered on February 25 and

March 7, 1825, in the Hall of the House of Representatives at Washington before the President, the Judges of the Supreme Court and both houses of Congress The fame of Owen's New Lanark accomplishments had already spread to America and few reformers have ever been favored with a more distinguished audience He exhibited a model of his community villages, in which the main building consisted of a hollow quadrangle, one thousand feet on a side, sections of which were marked out for schools and a university with lecture rooms, concert halls, laboratories and libraries The material wants of the population were supplied by a community dining room and by dwelling apartments, well furnished and supplied with gas, water and other conveniences He hoped, as the movement spread, to establish other similar villages, each independent yet all working together for the advancement of the common cause.

> Here it is [said Owen] in the heart of the United States, and almost in the center of its unequaled internal navigation, that Power which governs and directs the universe and every action of man has arranged circumstances which were far beyond my control, and permits me to commence a new empire of peace and good-will to men, founded on other principles and leading to other practises than those of present or past, and which principles in due season, and in the allotted time, will lead to that state of virtue, intelligence, enjoyment, and happiness which it has been foretold by the sages of the past would at some time become the lot of the human race.

It is not our purpose to describe the progress and failure of Owen's communistic experiment, but only to regard the part played by certain scientists, who were attracted to the New Harmony movement, and to consider some of the influences which they exercised upon the cultural and industrial growth of the Middle West.

For the development of the educational and scientific part of his social program Owen enlisted the cooperation of a wealthy Philadelphia geologist, William Maclure (1763–1840), who like Owen was a whole-hearted philanthropist and a firm believer in the need of social reform, although he differed from Owen with regard to some of the methods by which this end was to be achieved

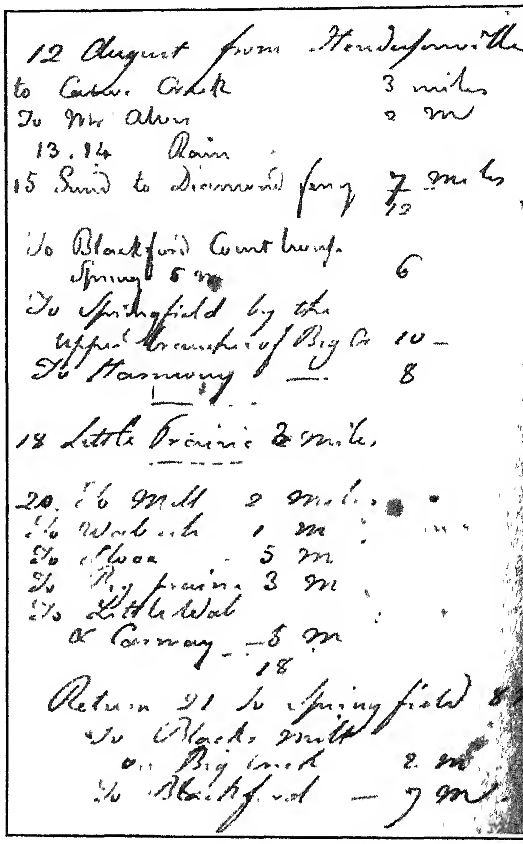

12 August from Hendersonville
to Cash Creek 3 miles
To Mr Alves 2 m
13. 14 Rain
15 Sand to Diamond ferry 7½ miles
To Blackford Court house.
Spring 5 m 6
To Springfield by the
upper branch of Big Cr 10 –
To Harmony 8
18 Little Prairie 2 miles
20. To Mill 2 miles
To Wabash 1 m
To [illegible] 5 m
To Big prairie 3 m
To Little Wab
& Carmany 5 m
18
Return 21 to Springfield 8
To Black's mill
on Big creek 2 m
To Blackford 7 m

FIG 5. RAFINESQUE'S ITINERARY OF HIS VISIT TO HARMONY IN AUGUST, 1818

FROM NOTEBOOK IN LIBRARY OF NATIONAL MUSEUM, WASHINGTON, D C.

Maclure, who was born at Ayr, Scotland, engaged in business at the age of 33 in the United States, where he soon became one of its leading citizens. In 1803 he was sent to France on a diplomatic mission and during this period devoted his leisure to the study of geology, which he pursued energetically after his return to the United States in 1807. Unaided, he began the self-imposed task of making a geological survey of the United States.

He traversed on foot nearly every state in the Union, crossing and recrossing the Alleghenies some fifty times and mapping the regions which he visited The results of this work were submitted to the American Philosophical Society and published in its Transactions for 1809 together with the first geological map of the United States This work was greatly enlarged in 1817 in Maclure's "Observations on the Geology of the United States" These pioneer publications of Maclure have won for him the title of "The Father of American Geology."

It has been the lot of few Americans to exercise so strong an influence upon the lives of their scientific contemporaries as William Maclure He took a prominent part in 1812 in founding the Philadelphia Academy of Natural Sciences, which included among its early members such distinguished scientists as the well-known chemist and geologist, Dr. Gerard Troost (1776–1850), and the eminent naturalist, Thomas Say (1787–1834), sometimes called "The Father of American Entomology," both of whom were Maclure's intimate friends. Troost was the first president of the Philadelphia Academy, holding office from 1812 to 1817, when he was succeeded by Maclure, who held the office for the next 23 years. Maclure was born a Scotchman, Troost a Hollander, Say an American, and to this group was soon added a fourth representative of another nation, the renowned French naturalist and traveler, Charles Alexandre Lesueur (1778–1846), whom Maclure in 1815, during one of his stays in Paris, persuaded to accompany him on a scientific expedition to the West Indies. Lesueur then continued with Maclure to America, where, after making a scientific pilgrimage through the North Atlantic States, the two friends settled in Philadelphia, at that time the center of American science. Lesueur was already well known in the United States and was quickly elected to the Philadelphia Academy of Natural Sciences and the American Philosophical Society, of which Maclure, Troost and Say were also members. These four men, of whom Maclure was the leading spirit, formed a group that cooperated closely for a number of years in making scientific surveys of the different states.

Maclure's interests in education and social reform were almost equal to his love for science Having been attracted to New Lanark by Robert Owen's work upon improving the condition of the working classes he very naturally became interested in this reformer's plans for a socialistic experiment at New Harmony. Maclure supported the program of his friend with characteristic energy. He contributed to the venture not only his personal support and one hundred and fifty thousand dollars of his own money, but he secured also the participation in the enterprise of his scientific friends Troost, Say and Lesueur. A group of several of these and other lesser lights in the fields of science, education and social reform made up the famous "Boatload of Knowledge" which sailed down the Ohio River from Pittsburgh in January, 1826, and after encountering delays from ice and other causes reached New Harmony on the 26th of that month.

Several scientists had visited Harmony before the arrival of Maclure and his friends. The most noted of these was Constantine Samuel Rafinesque (1783–1840), a pioneer figure in the history of American science. Much uncertainty prevails about his career and there are many contradictions in his published biographies He was born in Constantinople in 1783 of French-German parentage, and after a wandering boyhood, in which he acquired a love for natural science, he came to America in 1802. In 1805 he went back to Europe, where he spent ten years in Sicily in clerical and mercantile pursuits, continuing meanwhile his studies in botany and other

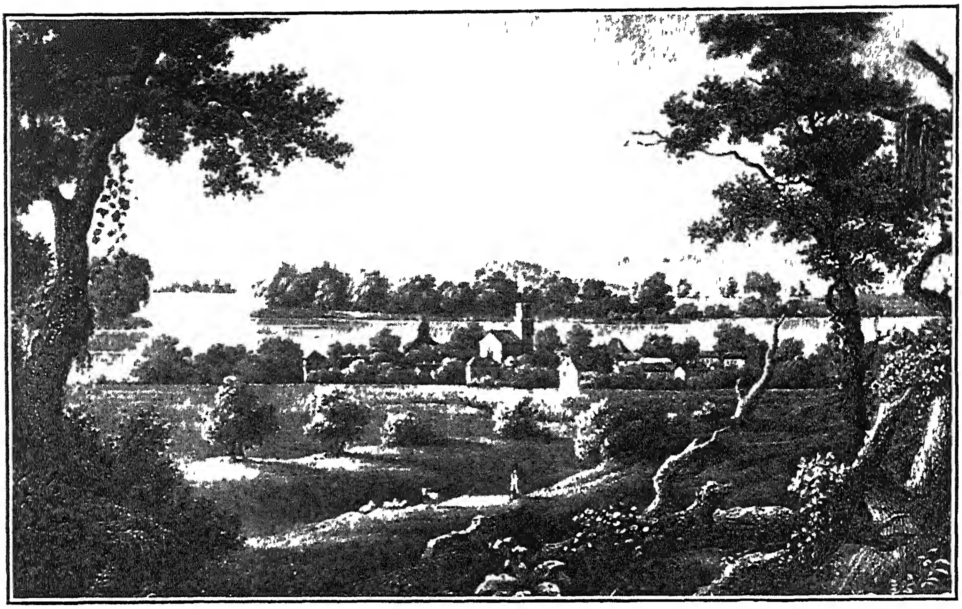


FIG 6 NEW HARMONY DURING THE OWEN OCCUPATION
FROM AN OLD PRINT.

sciences. He returned in 1815 to the United States, where he spent the remainder of his life in teaching and other miscellaneous occupations, but most of all in making extensive scientific excursions to various parts of the country. He was one of the first to study the plants, fishes and shells of the Middle West Unfortunately the eccentricities of this self-made naturalist have distracted attention from his contributions to botany and ichthyology. Long before Darwin he announced that new species and new genera were derived from previously existing forms Rafinesque's desultory wanderings took him to Harmony as early as August, 1818, during Rapp's régime, his itinerary with dates being indicated in one of his note-books. In his "Life of Travels" (Philadelphia, 1836, p. 56) he wrote in 1835

> I made an excursion to new Harmony on the Wabash, where dwelt the sect of Harmonists, and since famous by the vain efforts of Messrs. Owen and Maclure to establish communities. I saw there Dr. Miller who had a fine herbal and gave me some fine plants, we went together to herborize in the meadows

It has been stated in some of the biographies of Rafinesque that he was associated for a time with the community established at New Harmony by Owen and Maclure,[2] but this statement rests

[2] One of the many conflicting statements in the various sketches of Rafinesque Youmans in his "Pioneers of American Science" (p. 186) states that Rafinesque, following the course of the Ohio, explored for the first time the botany of the country and then came to Indiana where he was associated for a short time with the community then lately established by Owen and Maclure at New Harmony Call also in his "Life and Writings of Rafinesque" (pp 29–30) states that Rafinesque on his journey to the mouth of the Ohio "passed through New Harmony, Indiana, which was then one of the great scientific centers of the New World In that quiet town on the Lower Wabash dwelt Say and Owen and Maclure and LeSueur . . ." Actually Rafinesque (as shown by his "Life of Travels" and by his manuscript Notebook No. 18 in the library of the National Museum) made his trip along the Ohio and to Harmony in the summer of 1818, which was eight years previous to the arrival of Maclure and his scientific friends. Crawford in his excellent "New Harmony Movement" (p. 77) refers frequently to Rafinesque (whose name he constantly misspells) and commits the same errors as Youmans and Call. Many mistakes of this kind, one writer repeating another, have unfortunately crept into the biographies of early American scientists.

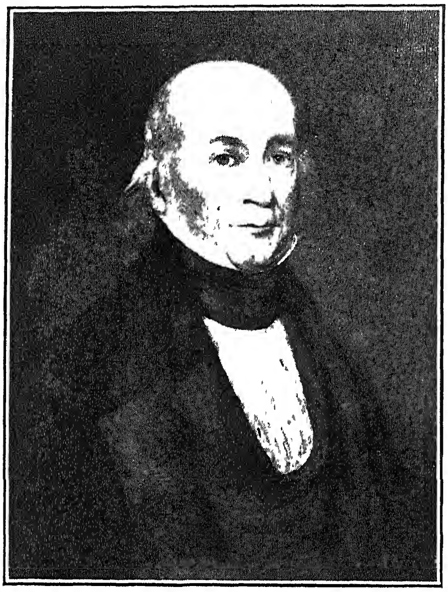


FIG 7 GERARD TROOST (1776–1850)
REPRODUCED FROM A PAINTING IN THE HALL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

upon mistaken evidence. Rafinesque had previously made the acquaintance of some of the New Harmony scientists, but as for joining them he states explicitly in his "Life of Travels" (p. 79) that while he had "some intention to join Mr. Maclure at New Harmony" it was well that he did not do so "since his views and fine College have been abortive." The peregrinations of this restless naturalist took him finally to Philadelphia, where, after living obscurely in great poverty, he died in 1840 at the age of fifty-six.

Other distinguished members of the New Harmony scientific group were the two youngest sons of Robert Owen—David Dale Owen (1807–1860) and Richard Owen (1809–1890) They were educated, like their older brothers, Robert Dale Owen and William Owen, in the school of Emmanuel von Fellenburg at Hoffwyl, Switzerland, where they pursued chemical studies which were afterwards continued under the celebrated Scotch chemist, Dr. Andrew Ure, in Glasgow. They sailed for America in November, 1827, and reached New Harmony in January, 1828, too late, however, to assist their father in staying the failure of his socialistic experiments

Among the famous visitors to New Harmony in the early period was Bernhard, Duke of Saxe-Weimar Eisenach, who arrived there during a tour of the United States in April, 1826, only a few months after the coming of Maclure and his "Boatload of Knowledge" The Duke's "Travels through North America," published at Philadelphia in 1828, throws interesting sidelights (Vol. II, pp. 106–123) upon the activities of some of the scientists in New Harmony. A few of his observations about the community are quoted.

> I renewed acquaintance here with Mr Say, a distinguished naturalist from Philadelphia, . . . unfortunately he had found himself embarrassed in his fortune, and was obliged to come here as a friend of Mr. Maclure. The gentleman appeared quite comical in the costume of the society . with his hands covered with hard lumps and blisters, occasioned by the unusual labor he was obliged to undertake in the garden. [p. 113.]
>
> I had an ample conversation with Mr. Owen relative to his system and his expectations He looks forward to nothing else than to remodel the world entirely; to root out all crime; to abolish punishment, to create similar views and similar wants, and in this manner to abolish all dissension and warfare When his system of education shall be brought into connection with the great progress made by mechanics and which is daily increasing, every man can then, as he thought, provide his simpler necessities for himself, and trade would cease entirely! I expressed a doubt of the practicability of his system in Europe, and even in the United States. He was too unalterably convinced of the results to admit the slightest room for doubt. It grieved me to see that Mr Owen should allow himself to be so infatuated by his passion for universal improvement as to believe and to say that he is about to reform the whole world, and yet that almost every member of his society, with whom I have conversed apart, acknowledged that he was deceived in his expectations and expressed their opinion that Mr. Owen had commenced on too grand a scale and had admitted too many members, without the requisite selection. [p. 115.]
>
> I passed the evening with the amiable Mr. Maclure and Madame Fretageot, and became

acquainted through them with a French artist, Mr. Lesueur, . . as also a Dutch physician from Herzogenbusch, Dr Troost, an eminent naturalist Both are members of the community and had just arrived from a scientific pedestrian tour of Illinois and the southern part of Missouri, where they have examined the iron and particularly the lead mine works, as well as the peculiarities of the different mountains. Mr. Lesueur has besides discovered several species of fish, as yet undescribed He was there too early in the season to catch many snakes. Both gentlemen had together collected thirteen chests of natural curiosities, which are expected here immediately. [p 122]

In these few extracts from the observations of the Duke Bernhard we catch a vivid glimpse of the scientific and social atmosphere of New Harmony as well as of the undercurrent of doubts concerning the outcome of Owen's socialistic experiment Matters in fact were rapidly approaching a crisis The presence in the community of a crowd of adventurers, speculators and loafers, who preyed upon the industry of those who were willing to play the rules of the game, proved too severe a strain upon human nature. Efforts were made to purge the society of undesirable members and plans were changed, all too frequently, to secure a greater degree of collaboration The population, however, was too dissimilar in sentiment and ideals for cooperative action. Dissensions long brewing between Owen and Maclure (the inevitable result of the contact of two such strong-minded personalities) terminated in an open quarrel over debts and property rights, the very issue which communism is supposed to prevent. The social experiment initiated in New Harmony was accordingly abandoned by Owen, although the possibility of establishing other communistic centers under more favorable auspices was cherished by this idealist until his death thirty years later

Following the end of Owen's communistic experiment came also the failure of Maclure's educational system of self-supporting industrial schools for children. With the final and permanent withdrawal of these two influential promoters the town of New Harmony went over to the established system of private ownership. The only reminders now of its two communistic periods under Rapp and Owen are some thirty old buildings of antiquarian interest and a library and museum of historical books and mementoes.

FIG. 8. THOMAS SAY (1787–1834)
FROM A LITHOGRAPH IN THE HALL OF THE ACADEMY OF SCIENCES, PHILADELPHIA.

The influences emanating from New Harmony as a scientific and educational center did not cease, however, with the retirement of Owen and Maclure but continued with increasing effect for many decades to come. Of the four Philadelphia scientists, Maclure, Troost, Lesueur and Say, who originally went to New Harmony, Troost was the first to withdraw, removing in 1827 to Tennessee, where he accepted in 1828 the professorship of chemistry, geology and mineralogy in the University of Nashville, an office which he filled with great distinction until his death in 1850. As state geologist he published many reports upon the iron, coal and other mineral resources of Tennessee as well as numerous scientific papers upon the fossils and other

geological remains of Tennessee, Missouri and other neighboring states.

Maclure, the geologist, the oldest member of the group, was the next to leave He departed late in 1827 for Mexico to recover his health, taking with him his friend, Thomas Say, who returned to New Harmony the following year Maclure died in 1840 while formulating plans for the endowment of workmen's institutes and libraries. Eighty thousand dollars under the provisions of his will were distributed in Indiana and Illinois for the founding of libraries. Although these collections have now mostly disappeared, they served in their time as the nuclei of many of the existing free public libraries of the Middle West. The present magnificent New Harmony library survives as a memorial to the philanthropic founder of American geology.

Thomas Say, the youngest member of the group, was the first to pass away. He continued to reside at New Harmony until his death in 1834 at the early age of forty-seven. Say is best known for his "American Entomology," the third and last volume of which was published in 1828 during his residence in New Harmony. His "American Conchology or Descriptions of the shells of North America" was printed at the School Press of New Harmony in 1830. The work is dedicated to his friend, William Maclure, and some of its drawings were made by his other friend, C. A. Lesueur. Other plates in this volume were made by Say's wife, Mrs. Lucy Sistare Say. The associations connected with this book make it unique in the history of American science.

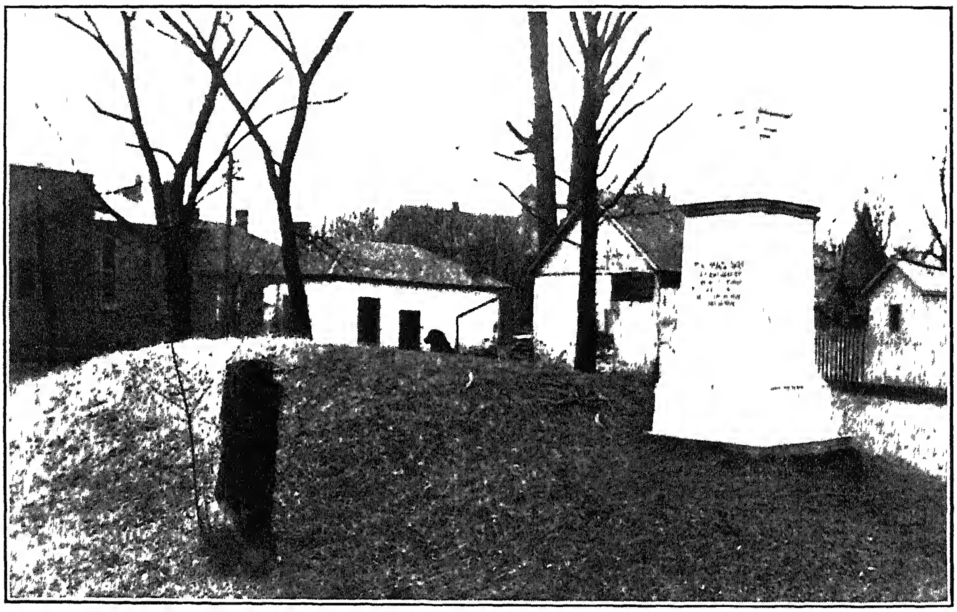


FIG. 9. THOMAS SAY'S TOMB AT NEW HARMONY

Charles Lesueur, the fourth member of the Philadelphia group of scientists, also resided for a time at New Harmony after the termination of the communistic experiment, the companionship of his friend Thomas Say being a strong inducement for remaining longer upon the frontier. During this interval he explored some of the mounds of southern Indiana and wrote numerous articles upon the fishes and mollusks of the Middle West, supporting himself meanwhile by his skill in painting and sketching In 1832 Lesueur and Say were visited

by the distinguished European explorer, Prince Maximilian of Neuwied, who with his scientific staff remained in New Harmony from October 19, 1832, to March 16, 1833. In June, 1834, Prince Maximilian passed through New Harmony again on his return eastward and Lesueur accompanied him as far as Vincennes. The Prince's American observations are contained in his two large volumes, "Reise in das innere Nord Amerika in den Jahren 1832 bis 1834," of which chapter VIII is devoted to New Harmony and the surrounding region.[3]

The death of Say in 1834 severed the last link which bound Lesueur to New Harmony, and three years later he returned to France, where he ended his days in 1846 as the curator of a natural history museum in Havre

With the passing of these original founders we come now to the later period of science at New Harmony, which began with the work of David Dale Owen, who, following his arrival in 1828, continued to increase his chemical knowledge by means of home experiments In 1831 he journeyed to England to perfect himself further in chemistry and geology and then after returning to the United States took a course at the Ohio Medical College in Cincinnati from which he graduated in 1837. He was appointed state geologist of Indiana in 1838 and, having made New Harmony his permanent home, entered at once upon the work which for the next twenty-three years was to be his sole occupation. After completing his preliminary survey of Indiana, during which he made unassisted his own field observations and performed his own chemical analyses in his New Harmony laboratory, Owen was requested by the U. S. General Land Office to make an extensive survey of eleven thousand square miles of the Northwest Territory in what is now a part of the states of Wisconsin and Iowa. In 1847 Owen was appointed United States

FIG. 10. CHARLES ALEXANDRE LESUEUR (1778–1846)
FROM A PAINTING IN THE HALL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

geologist to conduct a survey of the Chippewa Land District, a work which was later expanded so as to include more of the Northwest Territory. The results were published in 1852 in his "Report of a Geological Survey of Wisconsin, Iowa and Minnesota and incidentally of a Portion of Nebraska Territory." The head-

FIG. 11. DAVID DALE OWEN (1807–1860)

[3] Plate 2 of the Atlas of this work consists of a fine engraving of New Harmony as it appeared a century ago

quarters occupied by the Geological Survey at New Harmony was the old stone and brick fort or granary, built in 1815 by the Rappites, which is still standing. In this building were housed the large mineral collections made by William Maclure and his colleagues, as well as those gathered by Owen and his coworkers in their extensive surveys of the states of the Middle West. In 1856 this immense mineral collection was divided, a part of it going to the newly completed Smithsonian Institution[4] in Washington,

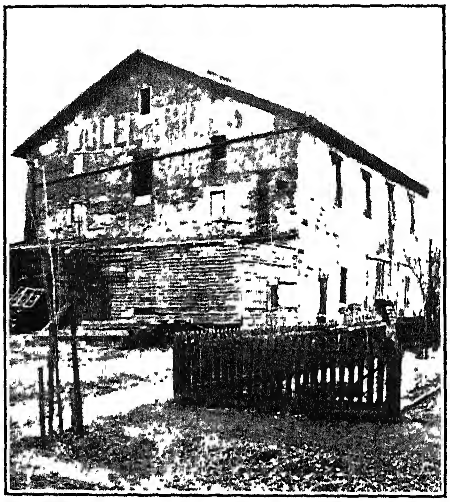


FIG. 12. OLD RAPPITE FORT OR GRANARY, NEW HARMONY

HEADQUARTERS OF UNITED STATES GEOLOGICAL SURVEY UNDER DAVID DALE OWEN (1847–1852).

another part to the Indiana State University at Bloomington and a third portion to the American Museum of Natural History in New York.

Following his pioneer work as United States geologist, David Owen conducted geological surveys for the states of Kentucky and Arkansas. The great influence of his work upon geological survey operations in Missouri has been stressed by Mr Arthur Winslow in an article upon geological surveys in that state. It is thus seen that starting from New Harmony as a center David Owen traversed in his geological work nearly all the states of the Middle West The arduous labor connected with these surveys eventually undermined his constitution and his active useful career was brought to an end on November 13, 1860

David Owen trained in his laboratory a large number of young assistants who afterwards became distinguished in geological work Among the noted men of science who were associated with him at various times may be mentioned his brother, Colonel Richard Owen (1809–1890), who succeeded him as state geologist of Indiana; Professor E T. Cox, the third successor in this office; Colonel Charles Whittelsey, the veteran Ohio geologist; B. F Shumard, of the Missouri Geological Survey and afterwards state geologist of Texas; F. B Meek, the well-known paleontologist, Dr. Elderhorst, who wrote a treatise on the blow-pipe; Dr Robert Peter, the well-known Kentucky chemist; Professor Leo Lesquereux, the noted fossil botanist, Professor A. H. Worthen, the state geologist of Illinois, and many others whose names might here be mentioned.

New Harmony was much frequented by scientific visitors during the life of David Dale Owen. Dr George Engelmann, one of the founders of the St Louis Academy of Sciences, rode on horseback to New Harmony in February, 1840, but missed seeing the distinguished company of scientists whom he expected to meet there. Another visitor was Sir Charles Lyell, the famous Scotch geologist, who in his second tour of the United States in 1845–46 came from New Orleans by boat to Mount Vernon, Indiana, and proceeded thence by stage

[4] It is worthy of note that the bill for applying the neglected James Smithson bequest to the founding of the Smithsonian Institution was introduced in Congress by Representative Robert Dale Owen, of Indiana, the oldest brother of David Dale Owen, on December 14, 1845, and was passed the following year. The striking architectural features of the Smithsonian Building with its brown stone castellated towers have been attributed to the joint plans of Robert and David Owen.

to New Harmony Of his visit there he relates:

> We spent several days very agreeably at New Harmony, where we were most hospitably entertained by Dr and Mrs David Dale Owen. . . Some large buildings, in the German style of architecture, stand conspicuous and were erected by Rapp: but the communities founded by him, and afterwards by Robert Owen of Lanark, have disappeared, the principal edifice being now appropriated as a public museum, in which I found a good geological collection, both fossils and minerals, made during the State survey, and I was glad to learn that by an act of the Indiana Legislature, with a view of encouraging science, this building is exempt from taxation Lectures on chemistry and geology are given here in the winter Many families of superior intelligence, English, Swiss and German, have settled in the place, and there is a marked simplicity in their manner of living which reminded us of Germany . . Say, the eminent conchologist, who died at the age of forty-seven, formerly resided at New Harmony and recently Prince Maximilian of Neuwied and the naturalists, who accompanied him, passed a winter here We found also, among the residents, a brother of William Maclure, the geologist, who placed his excellent library and carriage at our disposal. He lends his books freely among the citizens, and they are much read. We were glad to hear many recent publications, some of the most expensively illustrated works, discussed and criticized in society here [5]

With this pleasing narrative by the great Scotch geologist of the scientific and social activities of New Harmony as they existed ninety years ago we must bring our account of some of its relations to the history of science in America to a close. The New Harmony scientific movement, first inaugurated by Rafinesque in his pioneer exploration of 1818, then brilliantly pursued by Maclure, Troost, Say and Lesueur in 1826, and afterwards continued with such marked success by David Dale Owen until his death in 1860, may be said to have reached its terminus with the death of Richard Owen, who passed away in his eighty-first year at New Harmony on March 24, 1890 He was the last survivor of the brilliant family of sons of Robert Owen and, as professor of natural science in the Indiana State University from 1864 to 1879, did much to stimulate a love for science among the students who came under his instruction.

FIG 13. SIR CHARLES LYELL

It was a unique phenomenon that a pioneer settlement founded by uneducated German peasants should have become so quickly a great cultural center of broad cosmopolitan character, where

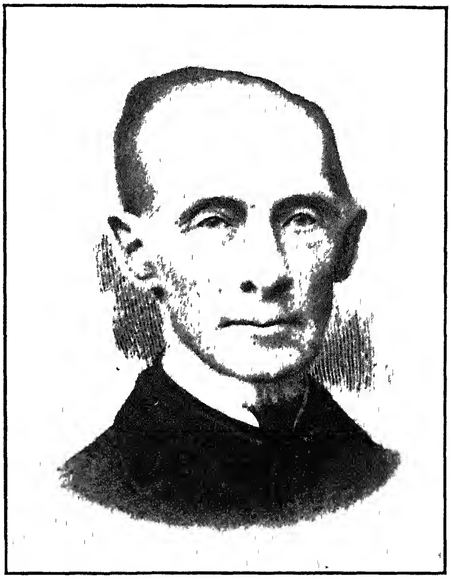


FIG. 14. RICHARD OWEN

[5] "A Second Visit to the United States of North America," by Sir Charles Lyell, Vol. II, London, 1849, pp. 270–2

not only American but English, Scotch, French, Dutch, Swiss and German scientists made their homes or their headquarters for various periods of time. It may be said of Robert Owen and William Maclure that while their socialistic experiment met with a speedy failure, they builded better than they knew. They blazed the way for those who dared to follow, and the work which they inaugurated contributed enormously to the cultural, scientific and industrial development of the Central States of our republic.

Although somewhat outside the scope of the present paper, it may perhaps be permitted in conclusion to devote a few words to a subject that is very pertinent to the New Harmony experiment, namely—the fitness of scientists to become the leaders in the legislative affairs of a community or a state or a nation. The question, as we have seen, dates back to the time of Plato, and it is widely discussed even now, especially in the scientific circles of England. Most generally it is the professional politicians who control the destinies of nations, and it is everywhere conceded that they have made a sad havoc of affairs, both national and international. But would congresses or cabinets of scientists have done any better? Professor P M. S Blackett, in his chapter on "The Frustration of Science,"[6] in the recent collaborative book of the same title, gives a very positive answer to this question.

There are some, he writes, who "conclude that the scientist should come out of his laboratory and turn his gifts of honest inquiry and objective judgment to help to put right the mess left by the politician. Such views are held quite widely, and not only by scientists. Of course, it is perfectly clear that any such hope is doomed to disappointment. Scientists, if in the position of politicians, would act like politicians."

We are not prepared to accept Professor Blackett's decision as final, although the very imperfect experiment at New Harmony, so far as it went, seems to justify the view that hope in the scientist as the sole savior of the commonwealth "is doomed to disappointment" Certainly, no one was better qualified than William Maclure, either as scientist or business man, to manage the affairs of a community, but the human material with which he had to work was so refractory that he had to give up the attempt. This, however, should not deter scientists, as a class, from taking a more active part than they have in the past, in the management of public affairs. The examples of Franklin in America, of Playfair in England and of Berthelot in France demonstrate that scientists can fill public offices with credit and distinction. What is needed in the present age is a greater representation of scientists in our legislative chambers, and perhaps the best way of accomplishing this is to humanize our sciences so that the public at large will appreciate more fully what science has done and is doing for the welfare of society. "All our science lacks a human side," wrote Emerson, and scientists might attain to that high position in the commonwealth, accorded them by the Utopian writers, provided more of them withdrew, as Plato suggested, from their academic retirement and helped to solve some of the intricate problems in that most difficult, yet most important, of all sciences—the science of human relations.

Although the communistic phases of the particular program of reform, initiated by Owen and Maclure, can be dismissed as unworkable, the value of such small-scale social experiments, as they so bravely undertook, should be recognized. Present emergencies should call forth on the part of all scientists a manifestation of the same courage and philanthropic spirit as were displayed by Owen and Maclure in their efforts to

[6] "The Frustration of Science," London, 1935, p. 133.

cure the social ills of a century ago Failure undoubtedly will follow failure and yet, in view of the recent stimulating address by Dr. George Sarton upon "The History of Science and the Problems of To-day," we are hopeful enough to believe that there will come eventually a fulfilment of the prediction of Robert Owen that such efforts, "in due season and in the allotted time, will lead to that state of virtue, intelligence, enjoyment, and happiness which, it has been foretold by the sages of the past, would at some time become the lot of the human race"

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IS THE UNIVERSE RUNNING DOWN?[1]

By Dr. W. F. G. SWANN

DIRECTOR, BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE

WHEN the American Philosophical Society did me the honor of inviting me to deliver the Penrose Memorial Lecture, I was told that I was to speak upon "The Second Law of Thermodynamics"; and, on inquiry, I found that I was also expected to make it intelligible to those members of the society and their friends who are not mathematicians or physicists On learning this, I bethought me of the medieval custom of trial by ordeal in which the culprit could only win freedom by performing some painful and impossible act. I began to wonder what sin I had committed, who might be my heartless enemy who was thirsting for my blood and in what unpleasant form he might be hoping to take it if I failed Then, some element of mercy for me seemed to have penetrated the hearts of my judges; or, perhaps, was it mercy only for the audience, to spare them the horrible spectacle of my torments during the ordeal? It was suggested that the title be changed to "Is the Universe Running Down?" The change has been made; but you will get the same speech in spite of that.

If I should be asked to give a brief illustration of what, in its usual interpretation, the second law of thermodynamics means to the world of inanimate matter; and if, in order to bring it home to your consciousness a little more vividly, I should be allowed to extend it beyond the scope of its legitimate application, but perhaps within the scope of its spirit, then to our universe, with its molecules and atoms of dead matter, with its worlds, its stars and its galaxies rich in structure and in principles of control, I should add the world of animate beings, with all its intricate laws of government and of social structure Standing beside me I should vision a cold and supercilious oracle who, in his statements to me, symbolized what, for this combination of animate and inanimate universes, would be the analogue of what the second law of thermodynamics would have to say for the inanimate universe alone. Let me cite, in the form of a dream, my supposed conversation with this oracle who guards within his consciousness the laws by which the universe is governed.

In my dream I saw much sadness around me, and I demanded of the oracle, "Can not the world be made better and richer than it is?"

"No," said the oracle, "it is bound for the dogs."

"But," said I, "may not a revolution occur which will improve the lot of those poor people whom I see yonder, and the lot of humanity in general?"

"No," said the oracle, "a revolution might improve, temporarily, the lot of the people you speak of, but it would destroy civilization somewhere else to such an extent that the world, or the universe as a whole, would be worse off than it was before. Even the temporary improvement in the people in whom you are interested would be but a passing phase, and their ultimate fate would be, if anything, hastened by their temporary good fortune "

"But," said I, "can matters never improve?"

"No," said the oracle, "they can only get worse in the long run—a house can fall down, but it can never build itself up again."

[1] The Penrose Memorial Lecture for 1935.

"But to pursue your own analogy about the house," said I, "might not yon house in falling down fall upon that factory over there, and, by hitting one of the machines, knock into place a certain bolt which I happen to know was always out of place, and which has so far prevented the machine from working. If that machine were set working, might it not build another house more beautiful and possessed of more intricate structure than that which was destroyed?"

"Ah! my friend," replied the oracle, "there might have been a universe in which such a thing could happen, but in our universe, governed by the laws which I have written upon a scroll in my pocket, I can tell you that such a thing can never happen; or, at any rate, if it did happen, it would happen with a degree of rarity such as to render the thought of its occurrence of no significance. But," the oracle continued, "before we can continue this conversation with profit, we must pause and come to a little better agreement as to what it is we are talking about. You stated that the second house which was brought into existence by the fall of the first might be more beautiful than the first. Before I can talk with you, we must have some measure of structure or beauty. Now I, the oracle, have a measure of structure; and in terms of my measure, the net structure in the universe would be less after the first house had fallen down."

"But, my dear Oracle," I interposed, "your measure of structure may be a very foolish one; and, in terms of my human intuitions, the actual structural content and richness of the universe may increase while in terms of your measure it diminishes."

"To that I agree," replied the oracle. "But the significant thing is this: in terms of my measure of structure, everything that happens in the universe tends to decrease the structure. You and your fellow humans may disagree with me that the structure is really decreasing; but my continual decrease of structure leads to an end-point. I can tell you what that end-point will be, and even you and your fellow humans will agree that the end-point which I vision is the limit of chaos. I, the oracle, say that we are moving towards chaos continually. You may not agree with me as regards the 'continually,' because you may not agree with my measure of structure; but call my measure what you like—call it a figment of the oracle's imagination, if you will—provided only that you accept the doctrines embodied in the laws of the universe which I have in my pocket, you will have to conclude that the changes of the universe are towards an end-point in which you yourself will admit that all structure has vanished. If you accept the doctrines to which I have referred, we may not agree as to the way in which we are going to the dogs, but we shall both have to agree that to the dogs we finally go."

"And what," I demanded, "is this final state of the dogs to which you refer?"

"It is one," he answered, "in which all men shall be equal. There will be no kings, no presidents, no government. All men will be exactly alike. There will be no criminals and no very good men. Nobody will have any ideas, and it will be impossible for anybody to do anything which he has not done before. There will be nothing that any one can do that every other can not do. Nobody will have any ambitions or regrets."

"Well," said I to the oracle, "at least we shall be safe, secure and stable."

"Yes," said the oracle, "you will be very stable—you will be dead; for in this chaos, as I see it, your very life, energy and potentialities for all action will be shared with so many things which now live not at all—with every grain of sand on the sea shore—that the amount which

will fall to the lot of any one of you will be small indeed.''[2]

And then, in my despair, I implored the oracle to tell me whether, consistent with holding to the doctrines contained in the manuscript in his pocket which he seemed to value so much, there might not be *some* way in which the chaos of which he spoke might grow once more to order.

''Come,'' said he with a malicious laugh, ''I will show you the only way in which what you wish can be done.'' And he took me into a desert where there was nothing but barrenness and sand. ''Let us wait a while,'' he said. And as we waited a storm arose, and the sand was blown hither and thither. When the storm was spent, I saw before me a little pile of sand which the storm had blown there.

''Look at that pile of sand,'' said the oracle. ''Do you think it very beautiful?''

''No,'' I replied, ''it is just a pile of sand.''

''Let us wait for another storm,'' said the oracle.

And we waited. Again the wind blew and the sand was scattered. When all was quiet once more, I saw before me another mound of sand. ''What have you there?'' said the oracle.

''I have a mound of sand,'' said I.

''Do you think it very beautiful?'' asked the oracle.

''No,'' I replied, ''it, also, is only a mound of sand.''

''But,'' urged the oracle, ''is it not of a shape different from the last?'' I agreed that it was.

''Then let us wait for another storm,'' said the oracle.

''But,'' I protested, ''what are we trying to do?''

[2] The technical reader will here pardon the invocation of a sort of principle of conservation of life which I have invoked into my analogy for purposes of illustration, a principle, of course, intended to typify the conservation of energy in the inanimate world.

''We are waiting,'' answered the oracle, ''until, by accident, the storm will some day blow the sand into the form of a cathedral, and by accident blow from afar such ingredients as mixed with the rain shall produce the cement which by accident may fall in such places as are necessary to cement the cathedral together and make a permanent structure.''

''But,'' I cried, ''such a thing is impossible.''

''No,'' the oracle said, ''not impossible, but (and he became inexpressibly cynical) highly improbable.''

And, as the oracle saw me meditating in sadness, he said: ''Come, my friend, I will tell you why all this is so. Before the sand and dust which made this desert were here, they formed the parts of beautiful rocks, and, for all I know, cities and buildings. In this form they were part of a rich and beautiful structure. Why that structure existed, I do not know; but this I do know—that the number of ways in which the grains of sand and dust can be arranged into beautiful structures is infinitesimally small compared with the number of ways in which they can be arranged to produce no structure at all. Now the principles which I have in my pocket tell me that while the laws of nature do not object to the existence of beautiful structures if formed, they do not conspire to produce them to the exclusion of others. They have no preference; and when they get a chance to operate on a structure and produce another, they give equal opportunity to all structures, the beautiful and the barren. When they first operate to change a structure they do not necessarily produce complete chaos at once; but, little by little, they work in that direction, and always waiting in the distance of time are those structureless forms outnumbering immeasurably all those with structure. These swarms of barren forms await their share in what

nature has to give them. They await their turns to exist. Each of them awaits in expectation for its little life. And, when nature has bowed to their wishes, her chance to find a way back to order is infinitesimal. She has left but the order of disorder. Change she may indeed produce, but the new thing she creates has but an infinitesimal chance of having any more form than that which it replaced."

And now we must say good-bye to our oracle. His purpose has been to give us at the start of this lecture, and I fear well into the heart of it, a faint preview of the kind of story which it is our task to tell. We must return to the realities of inanimate matter exclusively and speak in language appropriate to the things which compose it. Before making the transition, however, I should like to show a simple experiment to illustrate the last remarks of our oracle.[3]

On the screen is a mechanical slide composed of red beads and colorless beads. The red beads are at the bottom and the colorless beads are at the top. For this reason the slide has a kind of structure. I will rotate the slide a few times. You will observe that the beads are now more mixed up. I will continue the rotation and now, as you will observe, the red and colorless beads are fairly evenly distributed. If I rotate the slide a few more times, you will not doubt but that the beads will then occupy positions entirely different from those which they occupy now. Yet, I suppose you would be very surprised if in that new arrangement we found all the red beads once more at the bottom and the colorless ones at the top. And yet, why should you be surprised, for I may as well tell you that that particular arrangement is as likely as any other one —the present one, for example? You are surprised because, intuitively, you have sensed in this case the point which the oracle was trying to bring out. The number of ways in which the beads may be rearranged to look very much as they look now is enormously large compared with the number of ways in which they can be arranged with all the red beads at the bottom and the colorless beads at the top, in spite of the fact that the number of ways of producing different arrangements of that kind by interchanging the red beads among themselves, and the colorless beads among themselves, is very large. There is always a *chance* that when I rotate the slide a few times more I shall find all the red beads at the bottom and all the colorless ones at the top, but the chance is infinitesimally small. You may be interested in knowing what it is in the present instance. The slide contains 70 red beads and 70 colorless beads. I have calculated that if I go on mixing them and then examining the result, I shall have to go through the operation on the average about—and here I have no name for the number of times because it has 140 zeros after it—before realizing a case where all the red beads are once more at the bottom and all the colorless beads are at the top. It took me but few mixings to create disorder out of order, but to create order from disorder requires untold mixings. Wide and many are the roads which lead from order to chaos; but narrow and few are the paths from chaos to order, and few there be who find one.

The second law of thermodynamics had its origin in the study of heat. It was preceded by what is known as the first law of thermodynamics which is frequently regarded as an extension of the principle of the conservation of energy to those processes in nature which involve the production or utilization of heat. Those members of my audience who are specialists in physics or allied fields will not require that I give them a definition of the meaning of kinetic

[3] The nature of the experiment here shown will be sufficiently obvious from the text.

and potential energy, and they will understand and forgive me, if, for the benefit of the others, I speak rather naïvely about these concepts where the naïvetés are more or less irrelevant, even though I speak with sophistication in other parts of my discourse where the matters concerned are significant. It will suffice then to say that a body, or a machine, or contraption or assemblage of contraptions possesses energy if it possesses the power to impart motion to other bodies. It may possess energy in virtue of its own motion—kinetic energy as we call it—for then by impact with other bodies it may impart motion to them. It may also possess energy on account of its state, as is the case with a coiled spring which, though quiescent, shows when released that it possesses very much power to communicate motion to other bodies. The spring possesses potential energy. In the general case, any system taken at random possesses both of these kinds of energy—kinetic and potential. When the physicist has sensed in the crude form new concepts such as kinetic and potential energy, he proceeds as quickly as possible to invent some "yard stick," in terms of which he can make measurements of them, just as a golfer proceeds to measure the efficiency of different players by measuring for them something which he calls a "handicap." Now in terms of the measurements which the physicist had invented for kinetic and potential energy, it turned out that most of the simple processes of nature went on in such a way that if we considered the system as a whole, its potential energy might change into kinetic energy or vice versa, but the sum of the two always remained the same. The total energy was conserved. An example is to be found in a mass tied to the center of a horizontal piece of elastic. If the mass is pulled to the right, in the direction of the length of the elastic, and if it is then released, it will vibrate back and forth across its mid-point. At the instant when the mass is at its extreme right, and is just about to reverse its direction of motion, its velocity is zero; and, it has no kinetic energy, although at this instant the elastic is stretched to its maximum degree, and possesses much potential energy. On the other hand, when the mass is passing through its mid-position, the elastic is unstretched, and so possesses no potential energy; but the mass is now moving at its fastest speed and possesses much kinetic energy. In the intermediate positions there is a mixture of kinetic and potential energies, but in the example quoted the sum of the two remains constantly the same. At least this would be so if there were no friction. But alas! as you well know, there is friction, and you know that, as a practical fact, the mass would not go on vibrating forever. The sum of the kinetic and potential energies—the total energy of the system—mass and elastic—would diminish with time. Now, it is possible for you to trace in a reasonable manner the loss of some of this energy, for the air is moved by the motion of the mass. But if you perform the experiment in a vacuum, you will still find that the motion of the mass will die down in time. You will attribute this fact, and quite correctly, to the friction in the elastic itself. But then, I begin to wonder whether the elastic has anything to show for this loss of energy which it has somehow or other demanded and collected in virtue of its friction. If I look at it at the end of the experiment, it will look just as it did before. If I examine it sufficiently carefully, however, I shall find that it has been slightly warmed. We say that heat has been produced in it by the friction. Now, one of the outstanding advances of the last century was made when it was realized that whenever energy, in the more obvious forms of observable kinetic and potential

energy, appeared to vanish, heat was produced somewhere as a result; and, moreover, it was possible to derive a method for measuring this heat, independent of the way in which it was produced, and such that when measured in this manner the heat produced was the exact equivalent of the energy which appeared to have been lost. Before this time, heat had been thought of as a kind of substance, a fluid which could be forced into or out of matter, and which was itself conserved and unconvertible into anything else. Now, however, the mind began to sense this apparently mysterious thing "heat" as really a thing of no mystery. It itself was merely a form of energy, and was, in fact, in large part nothing more than the kinetic energies of the individual molecules and atoms. When a system appeared to lose energy and so get hot, there was no real loss of energy. The energy of the big things of the system, the wheels and springs and masses, was simply transferred in part to the little things, the atoms and molecules, where it existed in the very definite form of their kinetic energy, for the most part, but in a form more difficult to get hold of and use than was the form in which it existed in the wheels of the machinery.

And so we started to look longingly at all the energy residing in apparently useless form in the atom and molecules. Could we not get it back again into the wheels of the machinery? It was not lost. There it was in the molecular motions. But must it exist forever in idleness with no more purpose than to make the molecules dance about? Think what a wonderful thing it would be if we could only get all that energy back into service. At present, when we run a train from Philadelphia to Chicago, we burn up about sixty tons of coal. When the train has arrived at Chicago, it has sensibly the same potential energy as it had in Philadelphia, since Chicago is at approximately the same altitude as Philadelphia. Even though the train has scaled a mountain on the way, it has descended again by the time it has arrived at Chicago. It had no kinetic energy just before it started, and it has none when it is brought to rest in Chicago. What has become of all the energy provided by burning the sixty tons of coal? In the first instance, some of it went to boil the water in the boilers. The steam pressure made the engine run, and some of the energy went into that process. A large portion of it went simply to heat the condenser of the steam engine. But even the part that went to run the engine finally became converted into heat in the friction associated with running the train, in the operation of the brakes, and so forth. In fact, practically all the energy supplied by the sixty tons of coal finally went into that particular form of energy which is called heat—into molecular motion and the like. If only we could collect it in some way and make it function again, we could run the train back to Philadelphia without using any more coal. In fact, if we could do this kind of thing, we could make our trains and much of our machinery run forever with but one initial supply of energy. There would be no violation of the principle of the conservation of energy. No energy has evaporated into nothingness as a result of the train's going to Chicago. If this kind of thing could happen, most of our transportational and mechanical operations would involve nothing more than the continual transference of energy from one form to another and back again with the accompanying happy state of affairs for ourselves that we got where we wanted to go and did what we wanted to do without payment of anything. Now, our experience gives us the suspicion that we can not do this kind of thing, and that something is wrong with any assumption to the effect that we can. But what is

wrong? The procedure does not violate the conservation of energy. It does not "cost anything" in the long run, in the form of disappearance of energy, to do this kind of thing. If I should inquire of nature as to why I can not do this thing which I should so much like to do, nature would probably answer me thus: "My laws are more restrictive than the conservation of energy. They require that conservation of energy shall be obeyed, but they also require other things. Just because you keep your energy bank book balanced that does not give you the power to do anything else you please."

"But how," I demand of nature, "am I to know what things of this kind are impossible?"

And nature says, "If you could see all the detailed actions which are taking place in my realm, you would see for yourself which things are forbidden. There would, in fact, be no need for forbidding. These things could just not happen. To attempt to see the matter in this way would be too complicated. If I were to attempt to tell you all of the individual things which would fail if you tried them, the tale would be too long, and you would not see much connection between the parts. However, I find that by making one decree, I can settle the matter for you. There is just one thing which I tell you you can never do. I know that I need say no more, for I know that, without violating that decree, you would never be able to do any of the thousand-and-one things you want to do, and I don't want you to do."

That one decree is the second law of thermodynamics. It places a restriction upon the ways in which work can be obtained from heat. It looks as though the second law of thermodynamics was invented in the Garden of Eden, when the Deity said to Adam, "In the sweat of thy face shalt thou eat bread." The example which I have already given—the impossible process of collecting all the heat generated by friction, etc., and converting it back to work—is a rather complicated illustration of a process which could be seen to be impossible by means of the second law of thermodynamics, and I only cited it on account of the spectacularness of its nature. It is not easy to state, in non-technical terms, just what the second law of thermodynamics is, but I shall try to illustrate the essentials.

In the first place, it is necessary for us to heed the schoolmaster's warning to all beginners in physics concerning the necessity of a careful distinction between temperature and heat. Speaking crudely, temperature is a measure of the degree of hotness of a substance. Now a cup of boiling water and a barrel of boiling water are equally hot; but, it obviously took more heat to raise the barrel of water to the boiling point than was necessary for the cup. I think I need say no more than that to recall to you the distinction between temperature and heat. Physically, this heat is nothing more than the energy of the ultimate individual entities of matter's structure, such as the molecules of the heated body, and our problem concerns how we are to be able to get it out of the heated body and make it do something. If we say we can never make this molecular kinetic energy do any useful work we are wrong, because a steam engine works by making use of the molecular energy of the hot steam. But if we say we can always use molecular energy for useful purposes, we are wrong; for, if we could, there should be nothing to prevent us from draining all the molecular energy out of the earth by cooling it to absolute zero, and then using it to run all our machinery. It would finally go back to the earth again in the form of molecular energy when, as a result of the friction in the machines, it had become degraded back to the molecular form. Then when

it had gone back into the earth we could proceed to use it again. The earth would be as good as the widow's cruse of oil of biblical fame.

Now when we come to ferret out just how and how not, when and when not, we are able to utilize molecular energy, we find that the whole question boils down to this: We can get the molecular energy out of matter in a practically usable way[4] only provided that we utilize at least two pieces of matter, one colder than the other. Then we must take heat, *i.e.,* molecular energy, from the hotter body, but we must not use all of it; we must pay a tax to the body of lower temperature. The laws of nature make the inanimate world like a conglomeration of philanthropists of varying degrees of wealth (symbolized by the temperature in the case of the inanimate things), and characterized by the fact that you can get a donation from one of these philanthropists for a desired purpose, provided only that you promise to give some of the donation to one of the poorer philanthropists. If you try to get money from the philanthropists in any other way, nature conspires to block your operations so that you can only do it once.[5] Every transaction is thus accompanied by a kind of sales tax; and this tax is terribly high. In the case of an ordinary steam engine, it amounts to more than 70 per cent. of the energy transaction involved. In the inanimate world, nature seems to like to utilize every activity for the purpose of helping the poor (symbolized by low temperature bodies) at the expense of the rich.

Speaking crudely, we may say that nature likes to equalize temperatures. Everybody knows that nature likes to equalize the temperatures when two bodies of different temperature are placed in contact. We should be very surprised if, under such conditions, the hot body became hotter and the cold one colder. But the spirit of the second law of thermodynamics is to the effect that, even in the more subtle processes where heat is transferred between bodies through the medium of work, nature likes to equalize temperatures as a result. Nature is like human beings. Human beings will permit sections of society to exist in different states of prosperity, but whenever she gets a chance in the form of a revolution, things so arrange themselves that the revolution reduces the disparity.[6] And so, nature will allow things to exist at different temperatures, provided that we take precautions to guard them from loss of heat by such processes as conduction; but, if we give nature a chance by starting anything, she will take advantage of it for the purpose of making the temperatures of the various things more nearly equal than they were before. The second law of thermodynamics, which symbolizes the foregoing principle, is thus the most politically radical doctrine in the universe.

The second law of thermodynamics expresses itself by denying the possibility of processes which do not conform to a certain criterion. It tells us what we can not do. Our laurels earned by obedience to it are like the laurels of the saints, who appear to have been canonized for the most part for what they avoided doing. But it so happens that a sufficiently comprehensive statement of

[4] I use here the designation "practically usable way" as a symbol of processes in which, in the operations incidental to the utilization of the energy, the machine involved repeats continually a cyclical process.

[5] I am here citing an analogue to the case where, for example, in a system all at one temperature initially, one could obtain work by allowing a gas to expand and so cool, but could not get the system back to its original state with a net accomplishment of work as a result, without utilizing the principle of transference of some heat from a warm body to a colder one.

[6] However, this analogy must not be pressed too far; for human beings seem to possess the power to recreate the disparity again.

what can not be done sometimes implies a statement of what can be done. If we knew the complete mechanism of the universe in all its parts, the second law of thermodynamics would not, of course, add any information; but, when we do not know all about the processes, the second law can tell us something. Thus we know that water expands when it freezes; and, knowing this, we can deduce from the second law of thermodynamics that the melting temperature of ice must be lowered by subjecting the ice to a pressure. This result is, of course, well known as an experimental fact. When we squeeze a piece of ice, it melts, because its temperature, which was low enough to keep it frozen before the pressure was applied, is no longer low enough after the application of the pressure. However, apart from our experimental knowledge of the fact itself, it is by no means an *obvious* thing that the melting temperature of ice should be lowered by pressure. The opposite is true for wax. Without delving into the realms of atomic structure, we know far too little to see "just why" the melting point of the ice is lowered. The second law of thermodynamics relieves us of the necessity of knowing all about the process. It tells us the answer without our going through the complication of seeing "just why." It may appear a very trivial piece of information that the second law has given us in this case. Yet, if the melting temperature of ice had been raised by pressure; or, even if it had been lowered, but by an amount different from that predicted by the requirements of the second law of thermodynamics, I could take all the heat out of everything around and make myself a millionaire. It would then be possible, in principle at any rate, to construct a machine which would continually perform work by simply cooling everything that there was to cool. We could drink the heat out of our poor old earth, out of the sea, and everywhere, and could go on running our trains and street cars with the energy thus made available. Just as now we use the earth's coal, so, under these conditions, we could use its heat. I do not refer to the use we could make of its internal heat, owing to the fact that the inside is hotter than the outside. We could use that part quite in harmony with the second law of thermodynamics, the only difficulty being in getting at it. I refer to the heat which, under the postulated conditions, we could obtain from the earth even though all of it were at the temperature of its exterior. We could obtain a good deal of power in this way. We could obtain about ten thousand million horse power for ten thousand million years. Moreover, when we had used the heat once, and it had gone back to the earth, we could use it again. But, while the second law does not tell us the details of all nature's workings, she tells us that we can not do any such thing as this. Only by equalizing the temperature differences around us can we devise practical schemes for converting heat to work. As long as we have bodies at *different* temperatures, we can convert heat to work. If we have only a few hot bodies, we shall soon exhaust our possibilities in this respect, because the hot bodies will become cooled and the cold bodies warmed by the operation of the very processes we use for converting the heat into work; and, when all differences of temperature have been wiped out, our possibilities come to an end.

The second law of thermodynamics rests upon the fact that all the consequences which it has predicted have been found to be true experimentally. It is like a race-horse tipster. It lives on the truth of its former predictions. It will only continue to live so long as its predictions continue to be in harmony with the facts; but it has made such a lot of true predictions in the past that we have

become accustomed to trust whatever it predicts when it predicts new consequences.

When one has formulated the law of gravitation for the motion of the heavenly bodies, it is possible to see in terms of it just why the planets behave as they do; and, during the last century, a good deal of thought was expended in an effort to see just why the second law of thermodynamics should hold—to see just what detailed story of the atomic forces of nature could be responsible for this tendency of matter to seek always to equalize temperatures, not merely by the processes of conduction of heat from the hot to the cold, but by other processes as well. The mathematician got busy and showed that this tendency to equalize temperatures was the same story, but in other words, as one which would say that nature is trying to progress in such a way as continuously to make a certain quantity greater. That quantity was called the entropy. It was possible for the mathematician to calculate quite definitely in terms of such things as the pressure, temperature, and so forth, of any particular part of the universe, what the value of that mysterious quantity, the entropy, was, which had such a desire to become as great as possible. The quantity itself was not a very familiar looking thing in terms of our ordinary concepts. It was not like mass or velocity, or any one of the things we meditate upon in our every-day thinking. It was a sort of combination of these familiar things. But after all, we have no reason to be alarmed at that. For, if you should make, in precise terms, a definition of a golfer's handicap, it would seem a rather complicated and abstruse thing to one who was not a golfer. Nevertheless, it is a very useful thing in golf. It is the thing which has useful properties in telling part of the story of the activities of the golfer; and so this entropy was the thing which had the useful properties in the science of thermodynamics. Nevertheless, having admitted this new concept into the subject, the mathematicians and physicists still continued to try to see, by an appeal to the more detailed mechanisms of atomic processes, just why this quantity should have such an ambition to grow and grow in the universe. And the more the mathematicians thought about the matter, the more perplexing the problem became; for, without pinning oneself too closely to any particular form of atom theory or fundamental laws, it seemed that almost any of them would have no more desire to persuade the entropy to increase than to decrease. A simple illustration of the processes in this connection may be obtained by considering the case of the solar system; and it will be a little better if we complicate our ideas a little by laying a little more stress upon the features concerned with the mutual perturbations of the planets than is done, so that we picture a situation in which the orbits of the planets do not repeat themselves with perfect regularity, but on account of their mutual perturbations, go on changing a little from year to year. As a matter of fact, we do not have to apologize for this extension of ideas. It is really no extension at all. It is actually happening, only to a very small degree. The smallness need not worry us, we have plenty of time to watch it, and let us go on watching it. Suppose now at some instant we should suddenly reverse the velocity of every individual body, planet, satellite, comet. Then, the laws of gravitation tell us a remarkable thing. They tell us that the whole history of the solar system will redescribe itself backwards, and in every detail. In fact, as far as the laws of astronomy are concerned there is no more reason why the system should go through a sequence of changes in one direction in time than that it should go through exactly the

same sequence in the reverse direction. The feature which is responsible for this state of affairs is, moreover, not particularly characteristic of the law of gravitation, but is characteristic of almost any set of laws of the kind we had been accustomed to think of in physics, no matter how complex the laws might be. Thus if, with laws of this type, we should vision a set of molecules composing various pieces of matter which were originally at different temperatures and have shared their heat so as to be now at the same temperature, and if then we should suddenly reverse the velocities of all the molecules; or, more precisely, every part of the molecules which has motion, it would seem as though everything, every state and event, should take place backwards in time, so that the bodies would proceed to acquire a difference in temperature. The kettle which was put on the fire to get hot at the expense of the fire becoming cooled, would, under these conditions, become cooled once more and heat up the fire.

An equally remarkable situation is encountered by considering the well-known case of a box divided into two halves by a partition. The right-hand side is evacuated and the left-hand side is filled with air. I now punch a small hole in the partition and the gas rushes through the hole until both halves are equally filled, and then the process stops. You are content—I am surprised. One of the differences between the physicist and the layman is that the layman is apt to be confused and surprised when the physicist is happy and contented with a situation, while the physicist is surprised and worried when the layman sees no earthly reason why he should be worried at all. And so I invoke my professional prerogative of being surprised that the gas always shows a tendency to equalize itself, and never shows a tendency which would result in the equalized gas getting restless to the extent of causing all the molecules on one side to leave that side and go into the other side, like rats leaving a ship. Of course, I have no right to be surprised that there is no demon who takes it into his head to reverse the motions of all the molecules now and again. What surprises me is that none of these reverse processes seem to exist spontaneously in nature, since the ordinary physical laws we have been accustomed to think of, even with a wide range of possible extensions in their form, have no preference against these reverse processes. And so the physicist has been compelled to admit to himself that, within all reason, these reverse processes can occur, and do occur; and yet he has to see a way in which they do not result as a practical fact in what would appear to be absurd results in the light of our experience. The key to the dilemma seemed to reside in the principles exemplified in the example which I showed earlier concerning the red and colorless beads. I started with the colorless beads on the top and the red beads below. On shaking them, I have gotten them into their present state of more or less equal distribution. If I shake them again, I shall be surprised if they do not look very much as they are now. Yet, every time I shake them I redistribute them, and give them one of the many opportunities which exist for their taking another distribution. Among those many opportunities is that one which takes them back to the state where the colorless beads were on top and the red ones below, but I shall be very surprised if they find that pattern. Every time I shake them, I change them, but, of all the opportunities which exist for them on such a change, so many take them to another state in which they are mixed up in a manner which, as regards its essential characteristics, is the same as that in which they now are, that the chance of their getting out of this state is infinitesimal. The beads are some-

thing like a man in a maze. He tries once to get out and fails. He tries again and fails. There are so many ways in which he can try and yet stay more or less where he is, and only one way in which he can get out, that he may remain in the maze a long time. Yet, there is no difficulty in getting into the maze. He does that on the first try, just as I mixed up the beads from a state of order to one of chaos without any difficulty at all.

And so, our difficulty in the matter of bodies which are at the same temperature not starting to diverge in temperature, is not to be solved by denying the possibility that they can do so, but by emphasizing the fact that when they make any change, the path they take is so enormously more likely to bring them to another state in which their temperatures are still the same than it is likely to bring them to any other state, that the chances of the realization of such other states is infinitesimal. It may be of interest to cite once more the case of the box with the partition, and to emphasize that the reason that the molecules distribute themselves throughout the two halves equally, rather than in one half of the box only, is bound up with the relative chances of occurrence of the two states. I must not attempt here to define my terms too precisely, since to do so would require a long digression for that purpose. It will be sufficient for the spirit of the matter to quote a statement cited by Sir Arthur Eddington which I shall paraphrase slightly, to the following effect: "Suppose that a number of monkeys are provided with typewriters and are allowed to play upon the keys as suits their fancy, turning out pages and pages until they have finally typed as many letters as there are letters in all the books in the British Museum. Let us then bind these writings of the monkeys into volumes. The chance that the letters will fall in the necessary order actually to reproduce word for word all the books in the British Museum is enormously greater than the chance that in the room in which you are sitting, for example, all the molecules will be found at some instant in one half of the room. The same principles would apply in lesser degree to a number of people seated in a large auditorium. The number of ways in which we can redistribute them on the chairs is much larger if they occupy the whole auditorium, than if they crowd themselves into half of it. Yet, I surmise that if there is a conjurer on the platform, they will all be found in the front half if they can get in. May there not be something like this in nature. When I spoke of there being many more paths from order to chaos than from chaos to order, I only intended to imply that such *might* be the case. It must certainly have been so in the case of the beads. What is certain is that there are enormously more states of chaos than there are states of order. There are enormously more ways in which the red and colorless beads can be arranged and rearranged and still stay mixed than there are ways in which they can be arranged and rearranged with all the colorless ones at the top and the red ones at the bottom; but the number of ways in which a system can be rearranged so as to remain sensibly the same as it was before is not necessarily indicative of the number of opportunities for it to make the rearrangements. If you should distribute all the dollar bills equally among the people in this country, the number of ways in which by interchange of dollar bills you could keep the distribution of wealth undisturbed is enormously great compared with the number of ways in which the dollar bills could be redistributed among different people so as to retain the relative distribution of wealth which we now have, in spite of the fact that we do not in our different distributions limit ourselves to

the cases where the *same* people are always wealthy. Yet it does not result as a consequence that we find equal distribution of wealth. The reason is that the laws which govern the flow of wealth tend to favor the accumulation of wealth unequally. Indeed, the fact that if we started with an equal distribution of wealth we should soon realize an unequal distribution is very closely analogous to a situation which we would have if bodies originally at a uniform temperature made distribution of their heat in such a way that some of the bodies became very hot at the expense of others being very cold.'"[7]

And so it was necessary for the physicist to commune with himself as to whether he could gather from the laws of nature, as he knew them, enough to tell him that the probability of the existence of a state as measured by the number of ways in which it could be realized was really a measure of the chance that the system would get into that state. It is rather difficult to say in reasonably non-technical terms just how the physicist set about this, but I will do my best. Suppose, as an analogy, I imagine our solar system changed about. It is possible, in imagination, to take the elements which composed it, the comets and the planets, and set them off in other orbits, with the earth in the orbit of Halley's comet, for example, or in some possible orbit which does not happen to be occupied by any known comet; and to make corresponding modifications in the rôles of all the other bodies. I can have the moon going around the sun on its own account in a more independent manner than as the servant of the earth. It is to be supposed, however, that in this new arrangement of the heavenly bodies, I adjust matters so that the total energy is the same as before. The new solar system which we produce may be called a new possible state of the entities contained in the old one. I may perform this transformation again, and again, and in fact a very large number of times, and then contemplate this spectacle of millions of solar systems all the same as ours in the sense that they contain the same entities, but all in different states. I shall suppose that in this galaxy of states which I picture, I include a representation of every possible state which the elements of our solar system could exist in, subject only to all the states having the same energy. And now, if I am interested in discussing the kind of way in which the solar system changes spontaneously with time when in any one of its states, I have the whole picture before me, in the sense that there is a representative of every state which can exist. Like Joshua, I have commanded time to stand still so that I may look at the solar system for an instant; but I have improved on Joshua, for I have demanded that at one and the same time I may have a look at the solar system in each of the configurations which in its whole history it can occupy. Having had this vision, let time start moving on once more. Each of our pictures of the solar system will proceed to change. The way in which each changes will be determined by the laws of nature as applied to the particular state from which the change is to progress. Some of our pictures may represent very stable states, in the sense that the laws of nature are content to leave them very much as they are. Others may suffer rapid and drastic changes directly the laws of nature operate on them. In my original map-

[7] For the interest of those who are specialists in the subject, I would emphasize that we must not place too much weight upon a supposed difference between the human and the physical problem founded upon the different capabilities of the individuals who acquire different amounts of wealth; for, if we wish, we can invoke the different kinds of coordinates of the physical system as symbolic of different kinds of individuals. Then as to whether or not one class will be favored will depend upon the laws of the subject.

ping out of these various states I gave a sort of impartial picture of all possible states. Of course I could not draw an infinite number of pictures, but I drew in my mind's eye one state, then another which was a little different from that, then another a little different from the second, and so on, so that there was no particular state of the universe that any one could bring me such that I could not find something like it in my chart. I am like a criminologist who has drawn a lot of pictures of finger-prints differing successively from one another, and so complete that there is no criminal whom you can bring me for whom, on finger-printing him, I can not find one of the previously drawn records which is something like the actual finger-print obtained. And so, when I drew all my pictures of the solar system, I gave a fair representation to all possible states of it. But the laws of nature may not like my drawings. Nature may say, "Truly that picture number one thousand and three, which you have drawn, is a possible state of the solar system, but the solar system could never exist for any length of time in a state anything like it. I should drive it out of that state as fast as I could, and into one more pleasing to me."

"Well," I say to nature, "take these pictures which I have drawn as starting points, develop each of them as you will, and let me have another look later."

Then it may be that, as time progresses, nature will change certain of the pictures very little, while taking others, which she likes less, she may gradually modify them in such a manner that, when she has gotten things as she wants them, these states will be represented very poorly, all the original representatives of them having been guided out of them into states which nature likes better, and with no compensation in the form of a return from other quarters. If now I have another look at my modified pictures, I may feel aggrieved. I say to nature, "You have made a nice mess of my work of art. What have you done with ninety-nine per cent. of my nice pictures of the solar system? Why have you left only these few?"

"I didn't like the others," says nature, "they were terrible, so I changed them."

"But," I say to nature, "this is very unfortunate, for I want to tell you something. In nearly all those pictures which you have destroyed, there was one central idea, an idea common to all. This idea does not exist in the very specialized pictures which you have left me. As a matter of fact, such an overwhelming proportion of my former pictures had in them that central idea, that property, that I have told everybody that the idea was a fundamental consequence of the workings of your laws, in the sense that whatever state the solar system may be in, that property will almost certainly be found in it."[8]

"Well," says nature, "perhaps it was because I didn't like the property that I ruled it out. What kind of property was it anyway?"

"A very peaceable property," I reply, "one which does not disturb anything or produce any crises in the universe."

"Ah! a back-boneless property," says nature, "a fine property to work for in nature, a fine property to make a universe out of. No wonder I didn't like it."

Now let us point out the significance of our analogy. Just as I asked you to vision all possible states of the solar system in one picture, so the mathematical physicist has visioned in one picture all states of an assemblage of molecules and of distribution of energy among them. All but an insignificant propor-

[8] I need hardly remind the physicist that the property here spoken of is to be taken as the analogue of one of the properties (such as equipartition of energy) of the so-called normal state.

tion of the states were ones in which the molecules had gotten down to a sort of share-equally-for-all basis, of the kind I have symbolized earlier in this address, a condition in which the average energy of a group of oxygen molecules was the same as the average energy of a group of hydrogen molecules; a condition, moreover, in which things other than molecules had come to eat out of the trough. Each individual wave length of the spectrum of the heat waves of the radiant heat passing back and forth in an enclosure claimed an equal share of the energy. There are an infinite number of different wave-lengths, so that if the distribution of energy were made in this way among the molecules and among the waves there would be only an infinitesimal amount for each of the claimants. All but an infinitesimal proportion of the states of the molecules and waves associated with them possessed this lugubrious property. So the mathematical physicists appealed to the laws of nature to see whether they would not do something such as, for purposes of description, I have visioned them as doing in the hypothetical case of the pictures of the solar system. Would not the laws of nature exercise a sort of presidential veto against the overwhelming majority of representatives of the universe which were voting for chaos, and for the least amount of differentiation between the individuals, the least specialization in properties? Now, the truth was that the physicist did not know what the laws of nature really are, but he was able to show that, provided only that they were of what is known as a dynamical type, they would render no assistance, but rather would just let the universe run to the dogs.[9] I fear I can not pause to explain just what is meant by a dynamical system. The physicists will know, and, I fear, the others would get but little enlightment if I told them. It will suffice to say that the dynamical type of law is one which, while it permits a wide modification in detail, possesses certain characteristics much beloved of classical physicists. Provided then that the laws of nature were of this dynamical type, the changes which the laws permitted would allow the universe to wander indiscriminately through all the possible pictures which we could draw of it,[10] so that the chance of the universe finding itself in one of those barren states to which I referred would be, on this basis, overwhelmingly large.[11] As the physicists meditated upon this state of affairs in relation to the story of the older framing of the laws of thermodynamics, it turned out that that tendency of the apparently mysterious quantity, entropy, to become greater and greater, which tendency was the symbol of what the second law had to say—that tendency could be nothing more than an expression of the tendency of systems to seek states of greater and greater probability. In fact, the mathematicians were able to show how, by assuming that the entropy was nothing more than an expression

[9] I refer here, of course, to the implications of the famous theorem of Liouville, which is founded upon laws of the Hamiltonian type.

[10] A few reservations must here be made for the benefit of the technical reader. The argument given excludes the case of re-entrant paths, such as are associated with dynamically degenerate systems. The general implication seems to be to the effect that a sufficiently fine-grained consideration of the system would show that, in the last analysis, there were no absolutely re-entrant paths and that, given time enough, the system would occupy all states consistent with the conservation of energy.

[11] Even should we accept the implications here suggested, nevertheless, as I remarked twenty years ago in a discussion of this matter in the *London and Dublin Philosophical Magazine*, there is no reason for wonderment at our present condition. We may admit the extreme improbability of the existence of the universe in its present state, but we must remember that it is only during the very rare periods of existence of this improbable universe that there will be found in it those highly improbable beings like ourselves to study it.

of the probability, a very elegant story of the meaning of the science of thermodynamics could be built up. Entropy, as it had existed in the mind formerly, was simply a quantity which the physicist had accidentally stumbled upon and found how to measure because it had an important property. It now appeared that the physicist, when measuring entropy, was really measuring probability in spite of the fact that what he actually measured did not look like probability. The physicist was like a little boy looking at the log attached to the stern of a ship. What he sees is a pointer going round and round. What that pointer really measures is the speed of the ship.

Now the physicist likes to generalize. The idea which presented itself in examining the ways of molecules and atoms and heat radiation gave rise to the thought that all energy, even the energy of the internal structure of the atoms, and of the very electrons themselves, might be seeking to free itself from the bonds of structure and join the ranks of chaos where little pieces of it would have so much greater freedom to jog about from one thing to another without doing anything in particular. If we accept this idea as a principle—a starting point in itself—then there is of course nothing further to be said. From the practical standpoint the question at issue is "How far are we *compelled* to accept the idea?"

Now the failure of the laws of nature to cooperate in preventing the universe from going to the dogs is exactly in line with the requirements of the second law of thermodynamics over that region of experimentation which has given rise to the law. It must be regarded as an experimental fact that nature seeks to go to the dogs in some of her activities; and, any reversing principles which we contemplate introducing into the laws of nature must not deny the privilege of nature to go to the dogs when she wants to. How far can we go without running contrary to the demands of experiment and experience?

It is true that, in the sense in which the mathematician counts different states of a system, there is an overwhelmingly infinite number of states which are representative of the state of dead chaos which I have pictured earlier; but this, of itself, does not necessarily mean that there is an overwhelmingly large practical chance of the universe seeking an ultimate permanent existence in these states. We must not assume that some sort of infinitely improbable and complicated law of nature would be necessary to guide the universe out of chaos. Because there is so much water in the sea wherein I can drown, that does not necessitate an infinitely complicated ship to take me across the ocean. It is true that the law structure of the old classical dynamics provided no succor in the matter, but as every physicist now agrees, that law structure does not hold for atomic processes.

It is readily possible to invent a law structure which will avoid the unpleasantness of ultimate dead chaos. This is not the time to demonstrate the fact; but that there is nothing mysterious in it may be seen by citing again the analogy which I have already cited, concerned with the distribution of dollar bills among the world's populace. Apart from the laws governing the flow of business and of dollar bills, practically the same mathematical principles are available to show that the state of equal distribution of these bills among all the people is overwhelmingly the most probable distribution in the ultimate state, as are available to show that, in the case of the physical world, an ultimate state of chaos, of a universe run down, is overwhelmingly probable. As I have implied, the enormous odds in favor of equal distribution of the dollar bills have practical significance only in the absence

of controlling laws; and it is not hard to understand that the laws of economics and of man's behavior may be such as to prevent such a distribution of wealth.

If I should cite a still simpler example, but one in which the laws concerned are those governing animals, I would say that, if I should bring several million flies into this room, I could prove that the distribution of the flies which, by mathematical calculation, was the most probable distribution would be one in which each cubic foot of space contained practically the same number of flies. Yet, you all know what would happen if I put a bowl of honey on the table. I know that some of my physicist friends will point out that the classical theory has a way of taking account of things like the honey, and that the potential energy, in its control of the unequal distribution of molecular atmospheric density with altitude, for example, provides an illustration. To this I agree, but hasten to point out that this latter fact itself is just an illustration of how the cooperation of law structure with the numerical operation of counting states does produce an ultimate result in which the law structure can show its mark.

I feel, therefore, that, in our present rather incomplete knowledge of the laws of atomic processes, we can not say that the laws demand chaos as the ultimate fate of the universe. On the other hand, there is nothing in our present knowledge of those laws to deny such a possibility. In the light of this state of affairs, it is incumbent upon us to look around in the universe and learn what we can as to the way in which things seem to be going on as an actual fact. We find that the sun and stars are very hot. We have evidence that they have been hot for so long that had there been no sources available for the supply of heat, they must have cooled ages ago. All the more obvious sources of supply of heat which had been examined by the physicists, gravitational potential energy, radioactive energy, and so forth, had proved hopelessly inadequate; and it became necessary to draw upon atomic energy; and to go even further and draw even upon the energy associated with the very existence of such things as protons and electrons.

Modern physics has come to recognize a very close relationship between mass and energy, in the sense that if mass, in the sense that a particle has mass, is caused to disappear, then energy appears in proportional amount in the radiant form. If a number of protons and electrons are brought together, it is known that they lose mass; and it is believed that the disappearance of mass would be associated with the radiation of a proportional amount of energy. This relation between mass and energy, first sensed from the principle of relativity, has been verified in certain instances experimentally. The amount of energy which is the equivalent of the mass of even a drop of water is surprisingly large, so large, in fact, that the complete annihilation of the drop would result in enough energy to supply two hundred horsepower for a year. The conditions of very high temperature and pressure in the interior of the stars are believed to be favorable to this transformation of mass into radiant energy, and it is believed that in this source, by the devouring of its own substance, does the star refill its coffers of energy to pay forth continually to space that tax demanded by nature. While we do not have a complete picture of the passage of mass into energy in the sense that the materialistically minded would demand a picture, we are driven to believe that it occurs. No other source of energy seems adequate to explain the heat known to be continually radiated from the stars. Here then we see going on, as it were, the process of continual degradation of energy and of matter itself to the form

of ultimate chaos in the form of radiant heat energy. The logical end of this story would be the complete conversion of all matter into heat energy. It is true that the evidence of our experience teaches us that the devouring process would go on much more slowly when the stars were old; but eternity is long, and there is plenty of time. Is there any way back from radiant energy to matter? As a matter of fact, there is, and the method has been admitted by all physicists who are less than thirty-five years old, and by most of those who are older, as a perfectly respectable member of the society of physical methods, although the manner of its occurrence is at present exceptional. I must remind you that radiant energy exists in the form of definite units characterized in magnitude by the frequency of the radiation concerned. These units are called photons. Now the idea is that on certain rare occasions, a photon comes into such violent collision with the nucleus of an atom as to result in a kind of catastrophe. In this catastrophe nothing in particular happens to the atomic nucleus, but the photon becomes mathematically irritated in such a manner as to cause it to decide to change its existence, commit suicide and become resurrected as a pair of charged particles. If you should ask for a crude analogy, I suggest that you think of a spiritualistic seance. The photon is the ghost, the pair of charged particles constitutes the materialized ghost, and the atom is the medium. Now our ideas associated with the subject tell us that if our atom is at rest, this kind of phenomenon could not occur unless the photon had an energy enormously greater than that possessed by the kind of photons associated for the most part with heat. However, if the atom moves toward the photon with great energy so that it moves with a velocity comparable with that of light, and if we stand on the atom, the photon will appear like a photon of shorter wave length. This follows, in part, from the same principle as that which causes the pitch of a whistle to sound higher if you rush towards it, or more exactly from the theory of relativity. Thus to the moving atom, the low-energy photon will look like a high-energy photon, and the theory of relativity tells us that this fact will irritate the photon just as much as if it had been a high-energy photon and the atom had been at rest. The photon will change to a pair of particles and rob the atom of some of its energy to accommodate it in its new state of life. Were it not for the fact that we have to borrow the assistance of the high-energy atom, which high energy atoms are hard to secure in any large number in nature, this process would constitute a very suggestive one for the reconversion of radiant heat energy into matter. As matters stand, we have no suggestion from the laws of atomic physics as to the processes by which photons could become irritated without the presence of the atom. They do not possess the power to become irritated simply by their boresome existence; and, even if they did, a low-energy photon, without the assistance of an energy-lender in the shape of a fast moving atom, would not of itself have enough energy to enable it to change into a pair of particles. If we could see ways in which many photons could cooperate to produce particles, the path back to matter would be easier.

It is perhaps not without interest to contemplate a final state of the universe in which there were practically nothing but photons wandering throughout space, and compare it with what is taken by some as the starting point of our universe, a condition in which all the atoms of matter are distributed throughout a space of finite extent in the sense of the theory of relativity. It has been suggested that under such conditions the moving atoms will come together in clus-

ters under the influence of their motion and of their gravitational attraction, to form nebulae, which again under similar influences form clusters which condense to form the stars. From this simple beginning, there grows, through the action of gravitation, in feeding its energy into the motion of the atoms, a state in which the stars form and increase in temperature, producing in turn all those extraordinary phenomena such as transmutation of matter into energy, radiation of heat, and so forth, which we have only barely touched upon in this address. The question is whether, starting with a universe of photons, a similar, or rather an analogous, state of affairs can result. It would presumably be necessary to provide for laws and forces by which the photons could gravitate together, and produce conditions favorable to their conversion into matter; but, just as the effects of gravitation while present on a large scale are almost immeasurably small in the case of bodies of small size, so these forces, potent perhaps to form the basis of the recreation of the atoms, may be such as to prevent there arising conditions in which, in our ordinary experiments, a violation of the second law of thermodynamics would be found. In invoking such processes as those I have hinted at, perhaps a good test one might set himself as a test of the reasonableness of the idea is to inquire whether the process, violating as it does the spirit of the second law of thermodynamics, would, if it existed, have prevented people from going through exactly the mental processes they have gone through leading to the very discovery of that law, and to their subsequent belief in its generalized validity.

In conclusion, I would add that I hold no brief for trying to save the universe from its ultimate fate. My object has been simply to discuss the question as to whether or not that fate is inevitable in the light of our existing knowledge. The avoidance of that fate may involve some additions to our stock in trade of physical concepts. Among other things it may involve the cooperation of several photons in single acts, in the sense I have hinted, so that, to paraphrase the statement concerning the value of the work of him who can make two blades of grass grow where but one grew before, we may say that perhaps he who finds a way to make many photons act where but one would act before may have found a way to rebuild the universe.

IN QUEST OF GORILLAS

VIII. DRUMS IN THE FOREST

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

At Stanleyville we called upon His Excellency the Governor-General of the Belgian Congo and had the pleasure of learning that he was much interested in the gorillas and chimpanzees of the Belgian Congo and in our plans for preserving specimens for anatomical study. As we were then about to start on a trip north from Stanleyville into the great forest in search of chimpanzees, the governor very kindly advised us to go to a certain place southeast of Buta and north of the Aruwimi River, where chimpanzees were abundant He gave us a letter to M. Libois, who had been in charge of that district and knew all the details. Accordingly as soon as we could make the necessary arrangements we left Stanleyville in a camion, bound north for Banalia and Kole

That morning's ride through the great forest was very memorable as we passed beneath the extremely high and beautiful trees of the Prince Leopold forest reserve; many of these had shining gray trunks and immense spreading buttresses. I sat in the back of the camion on the baggage, facing the charming vistas of receding avenues of majestic trees

We also whirled by one village after another, usually extending along the banks on either side of the road. The village folks, especially the small children, did not fail to supply a continuous entertainment. As the grand whir and clatter of the big camion approached, loaded as it was with baggage and black boys, with four real "Bullamatari" on the seat and on top of the baggage, the little boys would run forward, hesitate and sometimes begin begging for "matabish" by gestures Then if one waved to them from the rear of the car they would respond with glee, running after the camion and waving as long as one kept it up and as far as one could see them One could even perform experiments in producing definite reactions at a distance For instance, if one waved his right hand, they would usually wave their right hands; if one waved both arms they would usually do the same If one started a dancing movement with his hands and arms, they would imitate it and then start dancing with their whole bodies. Even the men and graybeards, scandalized perhaps by such unexpected levity in a Bullamatari, would often break into grins and occasionally join in the uproar.

Miles and miles of villages shot past in this way and one wondered what effects the opening of thousands of miles of automobile roads was having on the culture and view-points of the inhabitants. If the natives had been more sedentary the effects would be still greater, but as they already had the habit of carrying their products many miles to the nearest market, it is possible that the presence of the camions affected them chiefly by bringing foreign merchandise to these markets and especially by greatly facilitating the collection and shipment of large quantities of native products to the nearest ports of export, down the river and thence to the outer world. Of course the existence of the roads makes it easier for the government to control the villages and in order to

—*Photograph by H. C. Raven.*

A 32-MAN-POWER FERRY-BOAT

PARTS OF FIVE SETS OF PADDLERS ARE VISIBLE.

facilitate this still further, a great many villages have been moved to the nearest road.

That morning the camion had to cross two rivers by ferry, and here was a novel and impressive display of the way the cultures and aptitudes of the whites and the blacks are cooperating harmoniously to spread peace and prosperity over the land. For the ferry-boat consisted of a row of six immense piroques, or native canoes made of hollowed-out tree trunks, tied together into a well-spaced series of pontoons by European bridge construction and supporting a platform for two camions The canoes are parallel to the course of the river, while the platform runs across them. After leaving the bank the gang of canoe-men, emitting the usual pandemonium, pull upstream on a line of rattan cable which is attached to floats; the end of the cable is fastened a long way above the starting-point When the ferry-boat has been pulled far enough upstream, the cable is dropped and the gang begin to paddle madly, amid a babel of chanting and orders. Swiftly the resultant of the current and the paddling shoots the burden across and obliquely downstream to a place just above the landing; then by clever paddling the front end swings around into place. The people here were especially joyous and tuneful, but we reserve further description of this choice spot till our return trip.

To the north of these two rivers the prosaic, low-roofed houses to which we had so long been accustomed began to be replaced by a type of roof which was produced upward into a sort of gigantic pyramidal fool's cap with a queer little topknot at the tip.

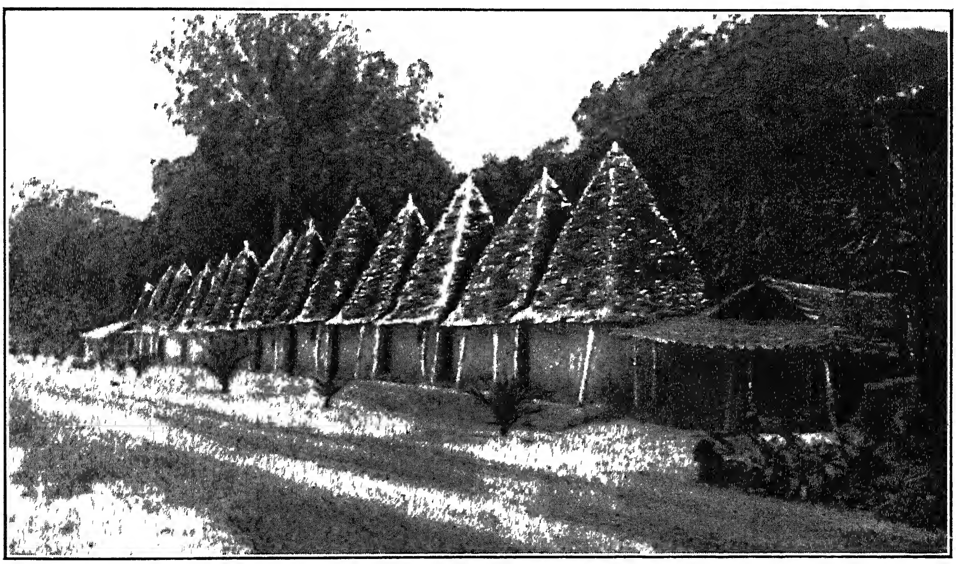
At lunch-time we arrived at Banalia on

the Aruwimi River, about ninety miles north of Stanleyville; here we were met by M S. de Medina, the proprietor of the local hotel. We learned that the district toward which we were headed had been recently flooded, that several bridges were down and that it would be impracticable to reach our objective in the short time available. We had also been told that chimpanzees were numerous in the forest around Banalia, this was confirmed by M. de Medina, who himself had killed many and who had several good black trackers to place at our disposal After a brief conference we decided to stop at Banalia, for a few days at least, and try our luck.

Then began one of the most interesting of all our experiences in Africa, for at Banalia we were in the midst of the great forest, on the banks of a typical tributary of the Congo, where elephants and chimpanzees abound, and among a people with a rich and picturesque culture.

When we entered the large, cool, thatched dining hall of M. de Medina's "hotel" we received an agreeable shock from the spotless table linen, the faultless service and the excellent food, the best we had had in Africa. The black genius that presides over the kitchen has been with M de Medina for twelve years and deserves to be decorated with the order of St. Boniface or whoever is the patron saint of innkeepers Of course M. de Medina, aided by his genial hotel manager, has created this remarkable state of affairs in Africa. The cottages for the guests are of brick with thatched roofs, cool and clean.

Even within the bounds of M. de Medina's estate we were in the midst of a native village, where something amusing or interesting was happening almost every minute But our first thought was of the beautiful forest on the other side of the broad river, so early the next morning McGregor and I got into a big piroque and were paddled, amid weird chants, a long way up against the current and almost under the overhanging branches; then we shot across and down to the vil-



—*Photograph by J. H. McGregor.*

A RESIDENCE STREET IN BANALIA

THE BELFRY PROBABLY ACTS LIKE A CHIMNEY, MAKING THE HOUSE COOLER AND CARRYING OFF THE SMOKE. IT ALSO ADDS GREATLY TO THE APPEARANCE OF THE HOUSE.

lage on the opposite side A valiant little water-snake pursued our big canoe and made many attempts to board us but was beaten off by the paddles of our black boys

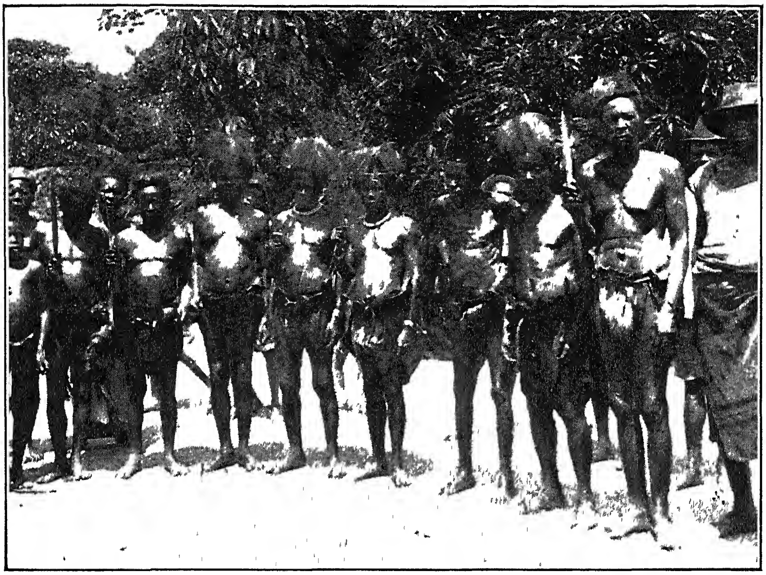
On this and other occasions some or all of us wandered in the dark and humid forest, listening intently for monkeys and chimpanzees; we saw fresh elephant tracks but very few monkeys, and we never got into close touch with the elusive sokomotos (chimpanzees) Even Raven, with all his long record of successful game stalking in many lands, tramped for days and often heard chimpanzees but was never able to deliver the definitive shot in the head that was necessary under our own requirements. The relatively few chimpanzees in this region are scattered over enormous forest areas, and whether one meets any of them is largely a matter of chance and of time. Accordingly only one chimpanzee was secured here in the week that we could spare from our journey to West Africa.

This dark forest was in most places not too difficult to get through and one seldom needed a machete, although many tangling vines and quite a few thorns would do what they could to check one's progress One day when there were all four of us and several blacks in the forest our trail was extremely tangled and I had not the remotest idea how to get back. Even the blacks were puzzled, one pointing in one direction and one in another, but Raven pointed a third way and soon we came out on the path near the place where we had entered.

The interior of the forest is a very peaceful, shady place, silent save for the chattering of small birds or the uproar of hornbills. Insects, except for the fungus-like nests of termites on the tree trunks, are not much in evidence and the same is true of other creatures, so that one may wander all day and see very little of animal life except for birds and a very few monkeys. Many of the trees are of enormous height The long clean trunks have a smooth light bark and immense diverging buttresses at the base. Huge "staghorn" ferns sprout from the trunks of the trees and serpent-like lianas coil

—Photograph by J H. McGregor.

A QUIET DAY ON THE ARUWIMI



—*Photograph by J H McGregor.*

IN FULL REGALIA

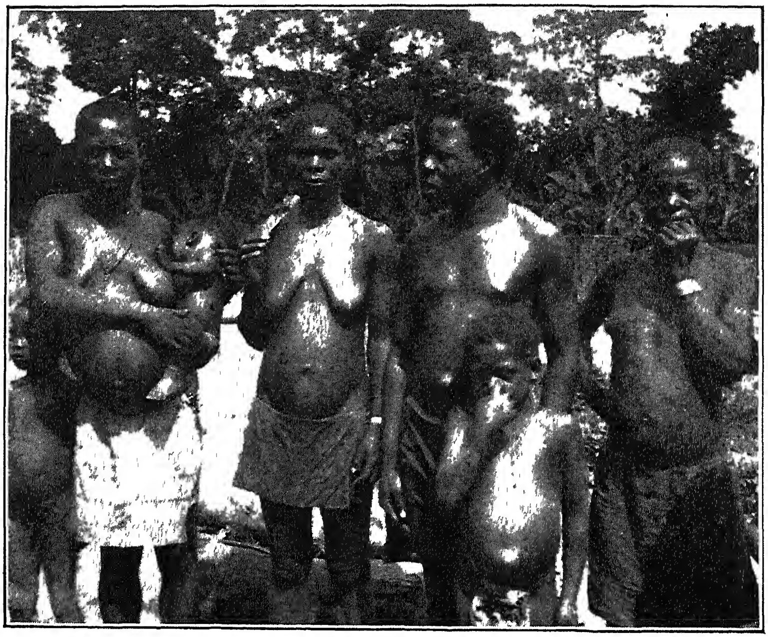
THE CORRECT DRESS INCLUDES A SHAKO, A HIPPOPOTAMUS GIRDLE AND A LARGE DAGGER-SHAPED KNIFE OF LOCAL MAKE

about the branches and hang down like ropes

The chimpanzees often come down from the trees when danger threatens and run away very quickly on the ground. Like the gorillas, they feed mostly on succulent green vegetation, but they are far more lively and emotional than these animals. They are very wary, perhaps partly because they are constantly hunted by both natives and whites.

The villagers around Banalia were glad to report to the white men the presence of chimpanzees in their neighborhood, as the latter do considerable damage to their plantations. Hence we made many excursions in M. de Medina's auto to villages in the forest through which the road ran Sometimes Raven and Engle would leave us to hunt in the forest, while McGregor and I would get pictures of the people and the villages. On the way we saw many things of interest. Here, for instance, is a black streak across the road, an army of ants on the march, carrying their pupae in thousands, with big-jawed soldiers seeking an enemy to attack A little further on, a cluster of butterflies, some of great beauty with iridescent blue wings. Here are the tracks of two big elephants that crossed the road only a few minutes before the auto came up and were seen by several natives, who told us about them. That unseemly uproar in the trees comes from a couple of hornbills, who utter harsh cries and fly with heavy whirring strokes, then glide for a while. There goes a "spot-face" monkey, making an enormous leap from tree to tree and getting out of harm's way as fast as he can. There above our heads is a huge wasp-nest hanging down from a tree, and M de Medina tells us a gruesome story of a native who was stung to death by the angry wasps.

And what people one meets along the road! Here is a grizzled old chief, plodding along on his way to a conference at a village a few miles up the road. He wears a huge belt of hippopotamus hide, which is prolonged in front of him into a



—*Photograph by J H McGregor.*

FRIENDLY WOOD–CUTTERS

great curving prow In this belt is stuck a long and beautiful steel blade with incised curved lines on the sides. On his head he wears an imposing shako of monkey fur, which adds to the grimness of his half-blind, wrinkled face. He is willing to be photographed in all his glory and does not need to be coaxed to accept a present of one franc.

Soon we come to a village, consisting of a long wide street with a row of "fool's cap" houses on one side and people resting in easy chairs in the sun Ladies obligingly fluff each other's hair, infants with swollen abdomens toddle about and bright little rascals of small boys roam in search of fun. Here the high court of chiefs is assembling and we quickly line up a dozen of these dignitaries; most of them have extravagant hippopotamus girdles and monkey-fur shakos like those of the ancient we have just left behind. They look very solemn and are probably getting ready to pass some fearful judgments upon the persons they are about to try. Of course all the village male gossips want to get into this picture, but they only laugh when we push them out of the way and give the francs to their "kings." We provide entertainment for the *hoi polloi* by throwing a few half-francs ahead of us for the little boys to race for, but there is always some big bone-head who can't resist the temptation to dive into the midst and try to get there first or to snatch it away from the milling crowd of boys. Such bone-heads never disobey when we roar at them and order them out of the way. (We are rather glad, in fact, that they don't disobey, as some of them are big enough to grab McGregor and me by our necks and knock our heads together; but in such cases we invariably assume the right to instant obedience, and the bluff always works.)

Some of the painted decorations on the plaster walls of the houses stand for horses, men, fowl, etc., and probably betoken membership in some fraternal order. These designs are exceedingly crude and ugly, in wide contrast with the serious and beautiful decorations

—Photograph by J. H. McGregor
THE VENUS OF BANALIA

of sword blades, spears, scabbards and household articles.

Then we go along to a village of wood-cutters, who have devastated many acres of beautiful forest, leaving half-burned stumps and dire confusion. As soon as the auto stops we are almost smothered in a crowd of grinning savages, who poke their big faces in the car and climb on the running boards. McGregor wants to get cinemas of them, and my congenial duty is to get the ice broken and the folks loosened up. We sit there a second or two and I suddenly point to a very attractive infant and in pantomime ask the mother for it. Fortunately she refuses, as I should hardly have known what to do with the squirming little creature, which is roaring its disapproval amid the smiles of the public. Then, for lack of anything better to do I point to a wooden bell, take it from a boy and signify my understanding of its use by putting it to my neck and shaking it, as their own dogs do when they have found the quarry shot by the hunters. Roars of laughter. Playing the clown has always been easy for me under congenial circumstances, so I get out of the car and by writhing gestures of shoulders and head suggest a village dance.

Instantly the cue is understood, people rush for huge "elephant's ear" leaves and tie them around their waists to serve as ballet skirts. Soon there is a madly swirling circle stamping and clapping and chanting and writhing, while McGregor reaps a harvest on the cinema. One poor old man looks on but does not join in the dance. Evidently for him life has lost its savor. I motion to him to join the ring, he gestures in a deprecating way, but I insist and soon he is stamping and whirling with the best of them.

Then all the dancers get "matambish" (a present) and we begin to take individual portraits. Here is one of the most brutal-looking blacks I saw in all

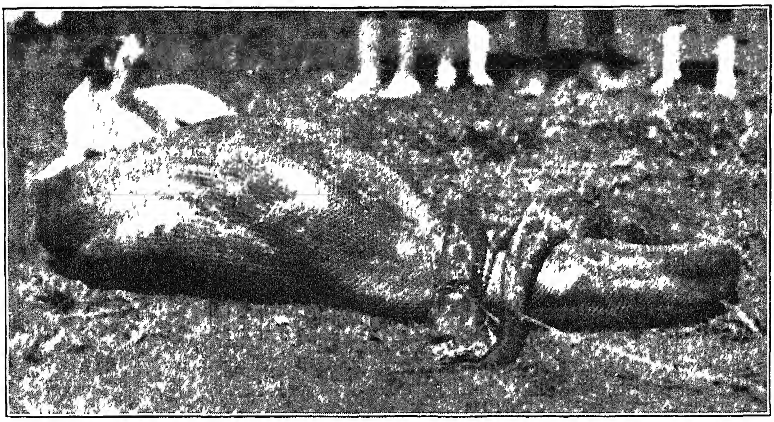
Africa—a short, big-muscled, flat-faced man with a red fez and with a lash in his hand. In the old days his lash would be a bloody weapon of tyranny, but nobody in the present crowd looks abused or afraid. Here are poor old females with leathern faces but with wheedling dulcet voices. Right next to them is a veritable black rosebud—a young girl to whom even the most crabbed misogynist must in fairness award a high quotient of feminine charm. She wears only a girdle and a narrow apron, and McGregor's discriminating cinema gets many an eyeful of this sable Venus de Banalia, recording her flowing contours, her dainty, well-poised head, her graceful arms, et cetera, as well as the delicate patterns in black tattoo pigment on her bosom and back. She has an indefinable manner of quiet confidence and good-breeding, and it is a pity that we could not make a record of her low and pleasant voice. But other candidates for the attention of the photographer crowd forward and when we try to pay her a franc, her young husband, the "captain" of the village, steps forward to claim it. He, poor youth, is entirely swathed in a grimy and forlorn suit of soiled ducks, but we are thankful that she is still a simple village maid, either too poor or with too great an investment of tattooing on her body to be eclipsed in a missionaries' Mother Hubbard. He can speak French quite well, and when later they call upon us at the hotel we send back cigarettes to the village folk and give a mirror to the little wife; she moves quietly past the tables of white folks in the dining hall, demurely balancing the small package on her head, in the dignity of her wholly modest black nudity.

That noonday we picked up Engle, who had had a long morning in the forest after chimpanzees, and later in the day we went back after Raven. After a week of constant hunting only one chimpanzee had been shot by M. de Medina's black tracker; unfortunately the animal is only a young male and the bullet has penetrated the body; we can only hope that the preservative fluid injected will reach enough of the capillaries to prevent serious decomposition.

Meanwhile around our little bungalow at the hotel amusing sights still abound. M. de Medina has two full-grown tame ostriches behind a wire enclosure opposite our front porch; once a day these awkward giants are allowed to come out and roam around the village. The fun begins when a boy with a stick tries to chase them back into their enclosure late in the afternoon. Of course they run everywhere but in the indicated direction, amid a satisfying uproar of scattering black females. One kick would knock the boy into "kingdom come," but he pursues them hotly. Finally when each ostrich gets near the gate he moderates his pace, lifting his knees high, and with upreared head and flapping wings stalks grandly into the enclosure. Another time M. de Medina's stallion takes it into his skittish head to begin bucking, pirouetting and side-stepping, and again the blacks scatter with endless jabber-quacking.

Meanwhile the dead chimpanzee, together with the four white men, proves a great attraction to the villagers, who crowd around to jeer at the chimpanzee's grotesque features and to watch the enigmatical proceedings of the white men who are embalming it. If they wonder about it all, they probably think we are medicine men of some peculiar cult.

On one occasion a man stepped forward from the crowd on our front lawn and introduced a puffy small boy, like a miniature drum major. The boy had a fearfully stodgy severe look, a great shako of monkey fur and a dwarfish rotund body. The people began to clap their hands in a slow measure and the boy started to puff his fat cheeks, roll his eyes and make his body jerk rhythmi-



—*Photograph by J H McGregor*

PYTHON AND GOAT, BOTH DEAD

cally, while the people droned rather than chanted the following.

Choomba, katoomba,
Choomba, katoomba,
Choomba, katoomba, katoomba

As the fat boy warmed up to his work, his movements and contortions became more and more violent and absurd, but he never relaxed his stern facial mask, or moved from the spot where he was standing; during the grand finale his agility was, to say the least, astonishing About this time we began to suspect that the *motif* of this dance was not altogether decorous. Afterward the boy solemnly passed his hat around and gave the francs to his father, or manager

That evening we watched for a short time a village dance, which was somewhat like an old-fashioned "Virginia reel," with "balance to partners" and "all hands around."

Another day a large group of women dancers came into the cleared space in front of the dining hall and went through an elaborate choral dance that lasted for several hours. The women were of all ages, from tiny children up to reverend beldames. They were fully dressed in their best cotton turbans and what looked like gaudy kitchen tablecloths. About half a dozen made up the orchestra, beating with their hands upon many kinds and sizes of drums, while the rest circled about them, swaying slowly in the dance Their movements were rather deliberate and mostly graceful and their music was sonorous and rather solemn. There was no wild whirling or corybantic revelling, and the manager of a New York black revue would doubtless have judged the performance impossibly tame. Apparently the missionaries in this locality have succeeded in hobbling the dance but not in suppressing the African's deep impulse for it

The leader was a very tall, comely and strong young woman with big jaws and friendly face, who gave out the song and swung her long arms and legs like a swaying elephant

I could not get the exact words of the chorus, but I wrote down quickly the sounds, as nearly as I could record them. For instance, one movement sounded to me like this·

BA LA, monomo NAY
BA LA, monomo NAY
Ye JAY JAY; ye JAY JAY, ye JAY JAY.

A similar theme was the following:

Am ba a JAY
Am ba a JAY
Am ba a JAY

Am gan a WAY
Am gan a WAY
A WAY, A WAY (drums)

One very fine swaying chorus with wonderful minor chords sounded to me like this.

Saúta mazoúri aláya
Aláya, aláya, aláya.
Ah! oúlalala, OUla, oulaLAYa
Aláya, aláya, aláya.
On sánga mazoúri aláya
Aláya, aláya, aláya.
Ah! moula JAYa, moula JAYa
Aláya, aláya, aláya.

The throb of the drums in several movements was like this

BUMP, billy um
BUMP, bum bum
BUMP, biddly um
BUMP, bum bum

But of course it is impossible to convey in this way any suggestion of the orchestration in detail as the several drummers varied the theme. Light refreshments and cigarettes were distributed at intervals during the performance and at the end the dancers received a franc apiece.

That evening the villagers came out into the plaza to dance

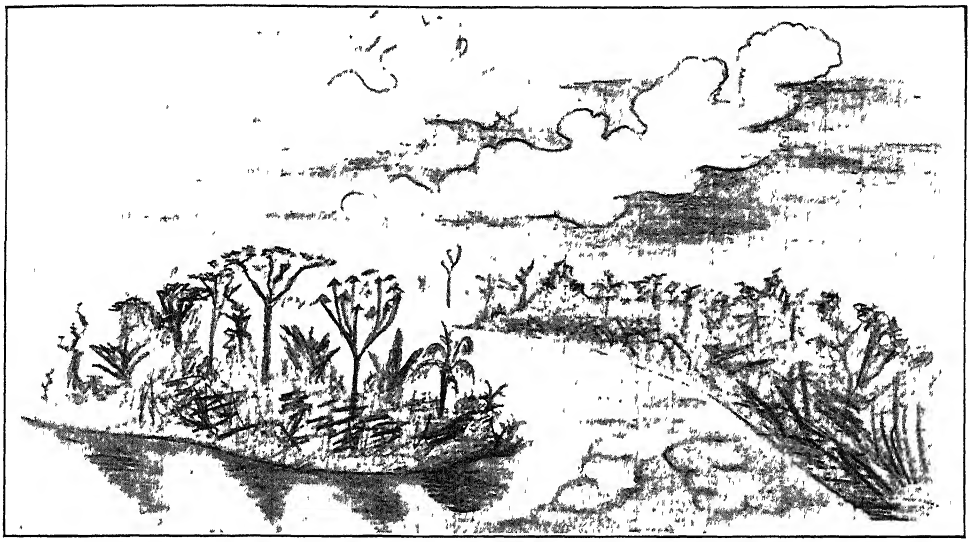
The little tom-toms and the bigger ones
Kept thumping rub-a-dub and then da-rum-dum
First a rub-a-dub and then a dub-a-dub,
While the black folks lightly footed it

The full moon flooded the earth with its silver light and threw the flat-topped acacia trees into delicate silhouettes, while the thatched huts cast black shadows on the pale ground But we reclined in deep sleep in our dark bungalow.

At breakfast next morning a native came in to tell M. de Medina that on an island in the middle of the river a big python had swallowed a goat and that the owner thereof begged the white men to come over, slay the python and recover the goat We got into a big canoe

—*Photograph by H C Raven.*

CROSSING THE RIVER



—*Sketch from author's notebook*

WE APPROACH AN ISLAND

and were paddled swiftly up river and across to the island. There deep in the long wet grass a python lay sluggish, trying to digest the goat M de Medina and Engle shot it in the head and McGregor spun the cinema as the sixteen-foot serpent was drawn out of his hiding. Then began a triumphant chant as the reptile was dragged to the canoe, paddled across the river and carried to our village But the operation of skinning the snake was interrupted by the owner of the goat, who was very indignant because the half-digested animal had been thrown into the river

The village a little way up the road from the hotel continues to afford interesting scenes When we go anywhere in a canoe we usually go to this village to get both canoe and paddlers. One day we saw a man cutting curved grooves in his steel blade; this he did by holding a flat piece of wood with a slightly curved edge against the blade, making the grooves with a hard steel point by following the edge of the wood.

The people have many well-made household utensils of wood, such as bedsteads, folding chairs (copied from those of the early explorers), cylindrical stools, long carved paddles Their houses also have openings on the riverside and they have many canoes.

One day the boys were playing ball on the smooth plaza by kicking the ball to and fro. A handsome little boy with very large eyes, about four years old, was quick to recognize my approving glances and elected me as his special friend, he ran out, took my hand and walked to the hotel with me, lisping "frangha, tambac" (francs, tobacco) as his little legs went fast beside me. A half-franc now and then served to cement the friendship. One morning his father, a fine-looking savage, called at our cottage with the little chap and his two other lads. He addressed a harangue to me which Raven afterward summarized thus: You like my youngest son; these two boys are mine also. I bring you present, very big chicken." Unfortunately I did not understand this graceful gesture (which of course implied a return present from me) and rather botched the situation by thinking he was trying to sell a chicken on the strength of my friendship for his child; so I

politely disclaimed knowledge of what he was saying and referred him to our cook However, the patient blacks are used to the rudeness of white men and no hard feeling resulted

I went out with this man twice in his big canoe, together with his boys and about ten other boys and men. In the middle of the afternoon, when the sun had lost some of its force, Engle and I started up river in this canoe with cameras and gun The paddlers dig their paddles quickly into the water and then, suddenly stiffening their bodies, jerk the paddles backward, relaxing suddenly as they withdraw them from the water Their chanting emphasizes these jerky movements When in shallow water the boat is punted with a long pole.

We go close under the overhanging branches, ducking our heads under them, and watch the muddy current swirling by Here and there small streams flow into the river and we see tempting vistas where we could paddle into the dark forest along the winding lane. We are looking for monkeys or chimpanzees (which sometimes come down to the river), but of course we do not expect to see them until after the chorus stops. We pass several islands with an impenetrable tangle of bushes and trees; then we punt past a quiet village on a high bank, and cut obliquely across a broad expanse of the river

As we near the opposite shore the chanting ceases and we drift in perfect silence down the swift stream We can hear the least sound in the jungle and can see a monkey make a huge and successful leap.

As evening comes on the immeasurably wide sky is piled high with colossal cumuli, like gods reclining at an Olympian feast. Rosy light is shed from their ambrosial locks and recumbent forms, while they rest upon the darkening nimbus.

We look down the long avenue of the river and as the greens fade we begin to discern a strange mirage against the gray mist It is the inverted image of a long canoe with moving paddles. Monstrous and sinister, the many-legged apparition crawls slowly over the river.

When we pass into the shade of the islands, the shadows of trees and bushes reach out to us with long jagged black projections that shake and tremble between moving bays of burnished brass.

When we emerge from behind the islands, the distant palms stand out as sharp silhouettes against the sky, while we move over coiling surfaces of purple and silver

Then the huge red sun descends and its fires are reflected from the under sides of the swelling, heaped-up clouds

On another afternoon Raven, McGregor and I went up the river with the same crew, again looking for monkeys and chimpanzees. Soon after we started the blacks shouted that there was a green snake on one of the bushes near by. The canoe was swaying, but Raven stood up, resting his rifle first on his hip and then holding it like a pistol, and shot the snake three times, the third shot nearly severing the neck. The blacks drew it into the boat and it proved to be one of the beautiful but terrible green mambas, about seven feet long, we cut off the head to preserve it and put it into a can, being careful not to touch the needle-like fangs.

Meanwhile the mist was gathering and soon it began to rain hard. We pushed the canoe under the overhanging branches and crowded into the hollow trunk of an enormous tree As the rain increased the blacks began to crowd in there also; finally our round-faced boy Musafiri almost fell down on us from his precarious hold above There was a fine display of gleaming eyes and beautiful teeth in this dark tree trunk, but after a while the atmosphere got pretty thick and as soon as the rain stopped we were

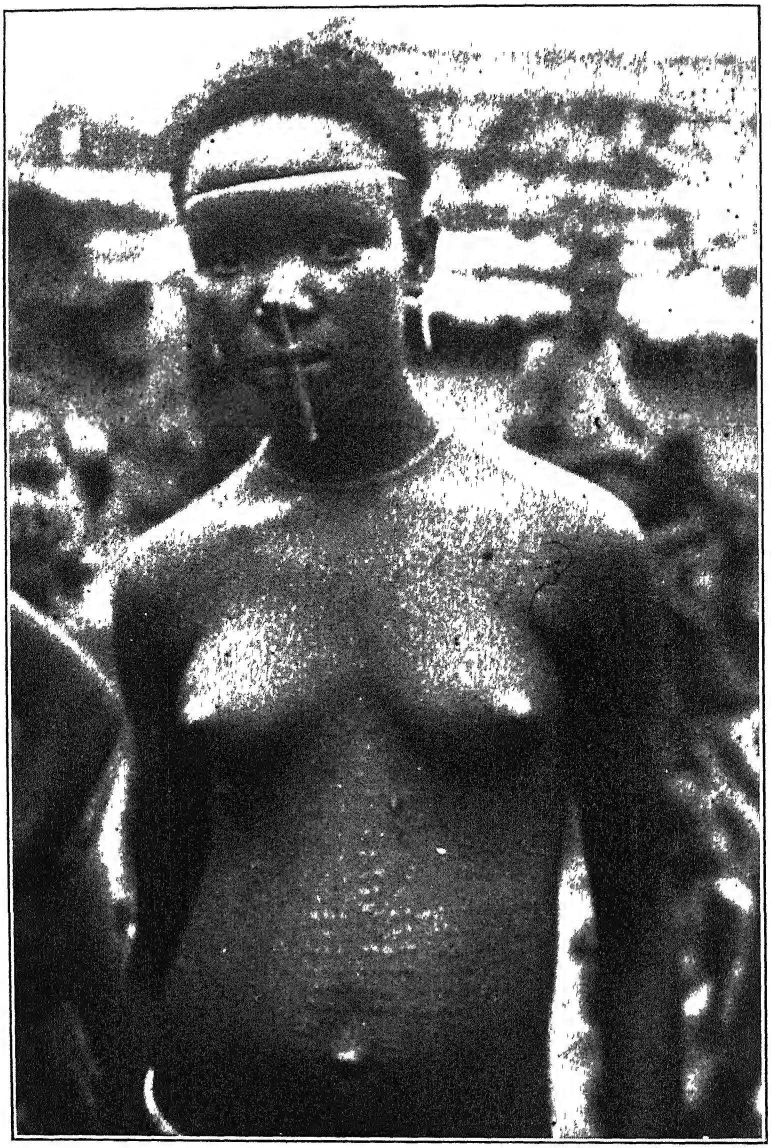
—*Photograph by J H McGregor.*

KEEPING UP WITH THE JONESES

glad to vacate in favor of the small ants, who seemed to resent our presence there After the storm we went on up the river, crossed it obliquely and drifted down again, witnessing another superb sunset This time the immense dark rain clouds were massed on one side of the river and the glowing golden and crimson clouds on the other

We had now been in Banalia about a week without getting any substantial results except in motion pictures, and it was deemed advisable for McGregor and myself to take the camion back to Stanleyville, to be followed later by Raven and Engle. So we said good-bye regretfully to Banalia and embarked on the camion for a most interesting ride back to Stanleyville, on which we had the opportunity of confirming and extending our impressions of the trip out. Once we stopped at a village in the forest to enable our black chauffeur's assistant to purchase some smoked elephant meat, presumably from the pygmies. The elephant had been denied a decent burial for a long time before the meat had been smoked and the meat itself was still pleading eloquently to be buried

It was not until late in the afternoon when we approached the first ferry that the fun really started. The ladies here had a queer way of sticking long stems of grass or short grass stalks vertically through a hole in their lips or horizontally through a hole in their noses; one old dame managed both decorations at once. They were somewhat coy at first, but as I felt that a little clowning might start things going, I stuck my head out of the back of the camion, waved my helmet and held a walking stick horizontally between my nose and extended upper lip as if it were a huge nose stick, then vertically as if it came through my lip. This started the laughter and McGregor reaped a cinemaful of the latest things in nose and lip sticks and chic tattooing of bosoms and stomachs After paying those who had been photographed we tossed a few francs for the boys to scramble after. While this was going on a couple of poor old souls with babies to carry, who did not feel equal to plung-



—Photograph by H C Raven

THE LATEST IN LIP-STICKS

ing into the crowd for francs, glided up to me with the most plaintive, pleading and persuasive soft voices and whispered "Matambish, matambish." I managed to slip them each a franc and climbed quickly on to the camion to avoid being mobbed by the others

We crossed the river in the manner described on page 518. But as we slid into the ferry-landing on the other side, the villagers there, no longer able to restrain their impatience, broke into a wild uproar and dance. Savage-looking men, slender maidens, youths and little children hopped up and down, dumpy women flopped up and down, and all loudly chanted their joy at the approach of the strangers, who were, no doubt,

about to fling largesse as the sower scatters the seed. As the camion chugged up the slope the population dashed at it from all sides and nearly stopped it with their rush. But a few half-francs thrown to one side started them all off in that direction.

When we reached the second ferry it was almost dark and the people were huddled in their houses, only a few coming out to paddle the ferry-boat across. After that we went over a long avenue of oil palms and upon arriving at Stanleyville we said good-bye forever to the unembalmed elephant meat and went in to dinner at the hotel.

Meanwhile Raven and Engle had been forced to give up our attractive tentative plan of making the rest of the trip across the continent by auto. We had hoped to go by camion northwestward from Stanleyville to Buta; there is a great elephant farm there for the domestication of the African elephant, and we hoped to get some interesting cinema records of these animals. From Buta we had planned to go northwest to Bangui in French Equatorial Africa and from there westward to Carnet on the Sanga River, thence southward to any one of the many places where the West African gorillas were reported to be numerous. But at the hotel at Banalia a gentleman who had recently been over the road in a light car told Raven and Engle that long stretches of the road were very bad, with bridges down and sandy stretches where a heavy camion would encounter great difficulties in getting through. In view of the fact that three out of four of us were expected to be home not later than the middle of January, it was deemed imprudent to risk such delays and it was decided to take the less interesting but surer way of going down the Congo River on one of the big river boats. Raven was therefore forced to make a trip to Stanleyville, back to Banalia and back to Stanleyville again, in order to get equipment ready for the river trip by the next boat, which was to leave three days later.

On his way back to Banalia the camion at night stopped in a heavy rainstorm to offer assistance to a car which was ditched and bogged. The white driver had compelled the natives to come out of the village to help him get the car out. One of the natives addressed a long harangue to Mr. Raven, complaining of their grievances in being compelled to work in this way; but they feared the police and the brass collar about their necks and so worked away until both cars were able to start, when they were doubtless glad to receive the francs that were paid to them.

The passenger in the first car was a very agreeable young American, Mr. Curtis Mitchell, who was making a quick trip across Africa, partly by auto; we later traveled with him down the Congo. Both cars arrived at Banalia late that night, and Raven and Engle came back the next day with all their baggage. Then began a hurried reassembling of all the baggage, part of which had been left at Stanleyville, and a strenuous time of resorting and repacking for the long trip to West Africa. It was decided that Engle, who had to return home first, should remain in Stanleyville for the boat following ours. This would give him an opportunity to visit the hospitals in Stanleyville and other cities on the Congo and to arrange for the photographs of feet, hands and wrists of natives, desired by Dr. Morton.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)

THE LIFE OF THE PEOPLE

By Dr. T. D. A. COCKERELL

EMERITUS PROFESSOR OF ZOOLOGY, UNIVERSITY OF COLORADO

When we consider the life of the people, we are concerned not only with the causes of death, but also with those innumerable influences which impair the vitality of the living. Among the lower animals, the reproductive powers are commonly such that of necessity the vast majority of the offspring must perish before reaching maturity. Were it not so, the excessive overpopulation would soon cause disaster, both to the species immediately concerned and other species living in the same country. The various means by which this overpopulation is prevented, the preservation of the "balance of nature," the struggle for existence which paradoxically succeeds because it fails, these are topics of the greatest interest to the biologist, and not without some significance in relation to sociology. The human species reproduces slowly, but even so, overpopulation soon results if all checks are removed. In 1927, when I was in India, there was an important medical conference in Calcutta. One of the principal speakers said: "For many years we have striven to teach the people of India how to obey the laws of health and control the preventable diseases. *Suppose we should succeed!*" India was already overpopulated, in relation to the existing facilities for living, and the poverty and disease were appalling. We went to Agra to see the Taj Mahal. On the way, the train began to fill up with all sorts of people, and on asking the reason, we learned that there was to be a partial eclipse of the moon. This rendered the Hindoos ceremonially unclean, and hence they had to go to Benares, and bathe in the waters of the Ganges, which naturally became contaminated with all the filth of India. The half-dreaded success of the medical officials did not seem to be imminent.

Has it "pleased providence" that these things should be? When we compare mankind with the lower animals, we find some important differences. In the first place, the long period of infancy (using that term in its legal sense) involves a large capital expenditure, not merely in money, but in loving care and thought. Look at any large crowd of people, and bring your mind to bear on the thought that they all were once babies, and had to be raised and cared for and educated. They represent an enormous investment, which should be expected to yield returns. Then again, the length of normal human life is such that its impairment through disease and through defects in the economic system results in so much misery that it could be maintained with plausibility that man is the most unhappy of all animals. As Wallace pointed out, while animal life is destroyed wholesale, it is for the most part healthy and happy, to be terminated suddenly and with little suffering. This is not universally true—consider, for example, the caterpillar with parasites slowly devouring its body—but even when death comes slowly, with a maximum of discomfort, the animal is not as sensitive as man, and has not his gift of worrying. Regarding life as a whole, in a purely objective way, it seems that nature has reached her greatest refinements of cruelty in her highest creation.

Very many people, in various places and in various times, have accepted all this either as the effects of blind fate or the will of a divinity. An oriental belief is that our sufferings represent punishment for misdeeds in a former life. The modern philosopher can see a certain justification for these ideas, but the pragmatic "man in the street" is coming

to a very different conclusion. He finds that he is endowed with intelligence, which can function to protect him from evils, and when he sees what has been done within a few years, he is appalled to think of the losses and wretchedness of past ages, due to causes which are now seen to be preventable. If he considers what providence or the deity has to say about it, he supposes that just as he is made to eat and work and move about, so also is he made to think and to apply the results of his thinking to his affairs.

Considering what we now know, and the probable results of researches to be carried on in the not too distant future, it is not too much to say that if we could overcome the psychological difficulties, it would be possible for the earth to be populated by people, not too numerous to be adequately supported by the means available, normally living to an advanced age and having essentially happy lives, free from most of the diseases and disabilities which now distress us. Under such conditions, we should not speak of the overproduction of goods. Every scientific discovery productive of more abundant resources, every invention increasing our command over the forces of nature, would in effect bring multitudes of human lives into the world, because it would provide the means for their existence. Our reproductive capacity would always be sufficient to meet the requirements.

According to the government mortality statistics, 1932, the death rate (excluding still births) per estimated 100,000 population in the registered area of the Continental United States was 1,755 in 1900, but only about 1,059 in 1932. It has steadily decreased in the last five years, notwithstanding the depression. Dr. H. Emerson, in the Encyclopedia Britannica of 1929, states that within the previous fifty years the birth rate in the United States has dropped from approximately 40 per 1,000 to 21. From 1919 to 1929 the rate dropped 16.3 per cent. in the birth registration area, and 17.9 in New York City. But this does not mean extermination. The population has steadily increased, the present registration area in the ten years ending with 1932 showing successively in millions (lesser fractions not counted) 90, 91, 93, 94, 96, 97, 98, 100, 101, 101. Considering modern restrictions on immigration, it is evident that the saving of life has given this result.

Dr. Emerson (1929) estimated that the people of the United States still suffered from preventable disease, cutting short the reasonable expectation of life by about twelve years. Suppose this twelve years to be added, will it be a genuine advantage? Will it mean the prolongation of senility, with waning powers and little satisfaction? Formerly, it might have appeared so, but to-day we not only prolong life, but also efficiency, and the later years need not be lacking in usefulness or satisfactions.

My friend, Dr. Frank R. Spencer, has given me the following figures. Since 1900 the death rate from tuberculosis has been reduced 64 per cent., for diphtheria 89 per cent., for typhoid fever 88 per cent. During this period the span of life has been lengthened 10 to 15 years. In 1900 only one child in five lived to be more than five years of age. Now only one in five fails to live past the five-year age. Cholera, typhus fever, yellow fever, the bubonic plague and many other diseases have been abolished from the United States. Dr. Emerson (1929) noted that fifty years ago one out of every four babies born alive died in the first year, now (1929) only one in sixteen died. All this applies to the registration area of the United States. In Great Britain there were astonishing gains even during the war period. In 1914 there were 57,994 deaths from tuberculosis; in 1924 only 46,756. In 1914 infants under one year died to the number of 105,681; in 1924, 65,259. At the same time, the Post Office Savings Bank deposits increased enormously, and the hours of labor were cut down

from about 55.5 a week to 48 a week. The consumption of potable spirits, retailed, was reduced to approximately half.

How has all this been brought about? Through scientific research, through education resulting in greater intelligence and through the enactment of laws. The general standard of living has been a potent influence. During the war, Dr. L. Farrand, then president of the University of Colorado, went to France as head of the Commission on Tuberculosis. He told us that while he was there ostensibly to deal with tuberculosis as a separate problem, he had in fact to consider the whole life of the French people: their habits, their sanitation, their food, the fresh air question, and so on. It must always be so, and when we ask how tuberculosis or any other preventable disease can be conquered, the answer is that it must be attacked on all fronts, with every means at our command.

Few people know much about the researches which have saved many more lives than the generals and statesmen have destroyed. I have a list of the Nobel Prize winners in medicine, 1901 to 1934. Some of the work has to do with particular diseases, as that of von Behring on diphtheria, Ronald Ross on malaria, Laveran on malaria, Banting and Macleod on diabetes, C. Nicolle on typhus. In many cases the prize was given for fundamental work in physiology, not at first appearing to have any particular medical significance, but actually building the very foundations of medical practice. One of the great problems confronting every physician, every sociologist, every teacher, every individual in his own life, is that concerning the precise significance and nature of heredity. We may not believe, like the Japanese, that we are penalized on account of personal sins in a former existence; but we know the germ plasm is continuous, and that we are part of ancient life, and are subject to its laws. For good or for evil, we have inherited certain qualities and potentialities, and we must make the best of them, in health or in disease. Hence it happens that T. H. Morgan, now of Pasadena, receives the Nobel Prize for medicine, although his work has been in genetics, principally researches on inheritance in the fruit-fly, Drosophila. Babcock and Clausen, in their admirable work, "Genetics in Relation to Agriculture" (1918), put at the beginning of their book a colored plate of Morgan's fruit-flies. Thus the truly epoch-making work of Morgan lies at the roots of both agriculture and medicine, although on casual examination it appears to be related to neither. It is interesting to note that the prize-winners come from many countries, six from North America. The influence of the Pasteur Institute in Paris and the Rockefeller Institute in New York is very noticeable. An important point is that most of the work, at its inception, or even throughout, was directed to the discovery of significant facts concerning life, without so-called practical or economic ends in view. At the same time, it was well understood by all the workers that more and better information about the workings of cells, organs and organisms would make it possible to deal more successfully with the problems of health and disease. It was not forgotten that unexpected practical gains of great importance sometimes emerge from a severely technical research into scientific theory. The effect of legal enactments, such as those of California relating to milk and the pollution of streams, need not now be stressed, though they deserve a lengthy discussion. It must be insisted that laws result from public education, and in a democratic country, at least, are the expression of the opinion of the majority. The formation of that opinion is a task, not only of the teachers and doctors, but of every intelligent citizen. On all occasions, appeal must be had to the knowledge we possess, and the fundamental laws of nature, to which we necessarily have to conform. Nature, in

imposing her penalties, has no consideration for ignorance or misinformation.

It is a mistake to suppose that everything must be done by law. It is difficult to make an estimate, but it is evidently true that the influence of individual and community initiative has been a leading factor in the great advances described above. A very good example is that of rickets, a disease principally of children, in which the bones are soft and bend under stress. I well remember hearing a great deal about rickets in England in my earlier days. Many efforts were made to restore the little patients to normality by means of supporting braces. But it came to be understood that the disease was due to malnutrition, and later the anti-rachitic vitamin was discovered. With our present knowledge, rickets is a preventable disease, and to-day the care of children is sufficiently intelligent, as a rule, to prevent it.

Very great gains have been made in respect to diarrhea and enteritis, the curve descending in nearly the same manner as that for tuberculosis. The reduction of infantile diarrhea has been a principal means of cutting down infant mortality. Curiously, the automobile has had a good deal to do with this. With the coming of the automobile, the horse has been nearly eliminated in cities, and thus the horse manure in which flies usually breed. Flies mechanically carry on their feet the germs of intestinal diseases, and when they were abundant were the indirect cause of innumerable deaths. However, it is not all due to the flies. The modern milk bottle and the modern regulation of dairies have been very important factors. When I was in Australia in 1928, I heard people lamenting the small population, and the difficulty of getting worthy immigrants. I heard that they did not yet know the closed milk bottle and I said, "Your best immigrants are your babies; improve your methods and save their lives." Still another factor is of great importance in connection with diarrhea and with typhoid. That is the pollution of water supplies with human excrement. Dr. Edward N. Chapman (*Colorado Medicine,* 1934) has shown that the principal rivers of Colorado are grossly contaminated with sewage, and has published maps showing the counties in which the death rates from typhoid, diarrhea and enteritis are abnormally, indeed scandalously, high. They are precisely those receiving the contaminated waters.

We have very good reasons for believing that great advances can be made, and will be made, in the future. We are largely depending on the results of research, but research will be sterile if not utilized. We could do very much with the knowledge already available. Dr. Gerald B. Webb (*Colorado Medicine,* October, 1933) notes that the infant mortality rate in 1932 was 58 in the United States, only 31 in New Zealand. It is true that New Zealand does not have the same burden of poor and illiterate people as many parts of the United States, and that consequently our problem is a much more difficult one. Yet it would seem that there should not be such a discrepancy as the figures indicate. According to the statistics quoted by Webb, in 1932, the infant mortality per 1,000 in Fort Collins was 143, but in Boulder only 32. Figures like these may be partly accidental, the actual numbers being small. Also, Fort Collins doubtless suffers from the numbers of Mexicans, who are imported for work in the beet fields. Thus statistics do not always mean what they seem to, and it is proper to investigate the facts back of them.

The most convincing figures are those which, taken over a long series of years, show a continuous change in the same direction. Thus the death rate from tuberculosis in New York City, per 100,000 population, fell as follows in five-year periods, beginning with 1890, and giving only approximate figures: 350, 300, 250, 225, 210, 200, 110, 100.

The last date available in this series is 1925. Many such statistics, equally convincing, can be cited.

Dr. F. Ramaley informs me that his brother, Dr. L. Ramaley, is concerned with public health in St. Paul, Minnesota, and goes to all the schools, public and private. They give all children the new preventive treatment with toxoid, for diphtheria, and here is the astonishing result. Before this program of vaccination they usually had about 700 cases of diphtheria annually in St. Paul; in the last two years they had only about 40.

It must not be supposed that all diseases are subject to efficient control. So much has been done in the past that it is hazardous to predict that control is impossible in any case. The extraordinary influenza epidemic of 1918, affecting most countries of the world, may have been due to some mutation of the causative organism, but in any case it came on us like an avalanche, and got quite out of control. It was a major disaster, like a great war, but fortunately without the legacy of bitterness and hatred following war.

Infantile paralysis, with which we are now especially concerned, is still essentially anarchistic, dealt with more or less blindly, as malaria and yellow fever used to be when I was young. But we do know this, that many cases, taken in time, can be practicaly cured by suitable treatment. It is surely a social obligation to see that such treatment is available for every stricken child, and such funds as are raised by the President's Ball, and by such organizations as the Rotarians, can be thought of as entirely well spent. Individuals may not be able to contribute very much, but all together, they can very easily meet the need of all the infantile paralysis cases in the country. It is a good thing to ask the public to contribute to such funds, not only as a way of raising the money, but also for the purpose of enlisting interest and securing cooperation. It would be a sort of misfortune if some individual or the government could take all such burdens off our hands, and leave us ignorant of and indifferent to the sufferings of the afflicted.

Finally, it must be said that many crippled or disabled persons, whatever the cause, can not be restored to normality by surgical means. For such persons it becomes a problem to make the best of the situation, and in some cases that best is extraordinarily good. A blind man (Fawcett) was once postmaster in England. Huia Onslow, who broke his spine when diving in the Tyrol and could only remain on his couch, his lower limbs useless, nevertheless did some scientific work of first-class quality, his most important paper being published by the Royal Society. Infantile paralysis, so disastrous in many respects, does not affect the mind. President Roosevelt, whether we approve his policies or not, must be recognized as having an extremely keen mind and strong personality. In Colorado we have Signa Carlson of Greeley, for many years confined to her bed, doing the most beautiful weaving, showing not only manual skill but excellent taste for color and pattern.

In the midst of a troubled world, in which there is so much to lament, so much to fear, it is encouraging to note the good that has been done and is being done. It is not stressed by the newspapers, and for the most part it comes quietly and with little public discussion. It is worth while to stress it more than we have done, if only to give us encouragement and hope for the future, and more respect for our species. Furthermore, it is something in which we can all have a part.

LIFE-SCIENCE AND MAN

By Dr. OSCAR RIDDLE

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We living in these many states are not a thinking people; yet there is in nearly all of us something which makes us wish that we, our neighbors and our children were just that. This wish is ours because we see our neighborhood and home and offspring thus made even more pleasant and valuable than they now are; and perhaps also because, in these days of shattered governments abroad, we could all feel nationally more secure if we were a more thoughtful people. Again, this wish which so many of us hold in common is enough to make us worthy humans; for, though we are not a thinking people this probably means merely that we have failed to train for thinking. A man becomes one of several rather different things according to the kind of training he gets. As a student of life-science and the background of man I am convinced that by nature man is more thoughtful than we now are. It should therefore be easy to increase this natural tendency, and the thought I bring here is that we can make ourselves, our community and nation better—more thoughtful and more secure—through training that our secondary schools should give.

The primitive savage is kept constantly alert by ever-present danger. He is constantly thinking about the meaning of what he sees and hears. His life and the continued existence of his tribe depend largely upon his quick and correct interpretation of sights and sounds and upon a sure and ready use of whatever his environment offers for his advantage. "Civilized man, freed from the stress of savage life, gets into the habit of not thinking. His actions become automatic. He gulps down whatever is served up to him" (Kerr). Civilization and sheltered childhood have removed many a stimulus to thought, and few things in the training of the citizen now seem more important than getting him back to the primitive habit of thinking constantly and effectively.

Early phases of human society, as represented to-day by nomadic hunting tribes, made much use of what we should now call science in the education of the young individual; that youth was taught to observe accurately the phenomena of nature, dead and living, to draw seemingly correct conclusions and to regulate his actions accordingly. In our own early history science undoubtedly played an equally important part in the training of the young. Even down into the Middle Ages, it supplied an appreciable part of the studies of the educated man. In later times, however, from the renaissance of classical learning onwards, science has been kept in the obscure background of our educational curriculum; the course of study for our high schools to-day remains largely literary and classical.

Thus this bit of history brings out the strange fact that almost coincident with the relatively recent period when some men began to get bits of really penetrating insight into nature—as others were doing with the classics—our training in science became poorer and less adequate than before. Moreover, in recent times, when our communal unit is not tribe or clan but thickly populated nations, we are most removed from tribal guidance in the study of nature, and also decidedly most in need of a common

knowledge and interpretation of the crowded world in which we must all live together. It would seem quite impossible that our modern bee-hive aggregations of men can satisfactorily or even actually persist without wide-spread familiarity with the nature and resources of ourselves and our communities. Because of the large extent to which personal adjustment must be made to other living things we shall now and hereafter need to make large use of the principles which rule in the living world. Life-science has become not only a great treasury of vitally important knowledge; it is also a method of learning how men may live together.

For some centuries the sciences have of course had a sort of home in the universities. But only within the life-span of many men now living have any of the sciences been generally considered proper objects of study outside the college. In his essay entitled "What Knowledge is of Most Worth," written some seventy years ago, Herbert Spencer set down the plainly convincing reasons for the special place of the sciences in general education. At present the minute amount of biology taught in the secondary schools of this country gives so poor, and often so wrong, an idea of what is in mind here that I use the term "life-science" instead. Since Spencer discussed at length the place of biology in education and since the subject was ably restated a decade ago by Professor Kerr (*Nature,* August 14, 1926) of Glasgow, my own presentation can be neither very original nor new; but so rapid has been the development of life-science that each decade provides a firmer basis for a restatement of the special values of this science to youth and to the training of the future citizen.

The writer Joad has well said: "One of the most disquieting facts about modern civilization is the failure of our social wisdom to keep pace with our material power. Science has equipped us with powers fit for the gods, and we bring to their use the mentality of babes and schoolboys." In considering this thought let us follow Kerr in indicating that in the new age it has become difficult or impossible for the untrained citizen to choose between true and false leadership to "social wisdom." Yet, at all times and among all peoples, the welfare and success of man have been closely related to his selection of leadership. In our day science and industry have given us such facilities for distributing the printed and spoken word that the method by which we humans formerly chose our leaders has been much disturbed. Primitive tribal communities, whether small or large, usually selected an outstanding personality—their ablest man—as their chief; and without such leaders during a half-million years one may well wonder how many caves and forests would now shelter the scanty survivors of the human race. But, along with their many blessings, modern printing and particularly the ultra-modern talking picture and radio provide the new disturbing factor—since they give enormously increased importance to elements of individual personality quite distinct from general strength and capacity, mental and physical. Conspicuous among such elements are oratorical power and skill in pleading special causes. The real leader is no longer forced to the front by the sheer power of his outstanding constructive ability; to a great extent first place is now taken over by the power of effective writing and speaking. Responsible posts of leadership of public opinion and of the modern state have thus become accessible to the skilled orator, even though his constructive ability in statesmanship may be of quite low order. America and the world now require a new defence

against their inevitable orators, mimics and emotional giraffes.

Clearly this development involves serious dangers to all peoples. It seems equally clear that one of the main tasks confronting each community is the devising and setting up of those educational safeguards which alone can be efficient against these dangers. Though all science probably provides partial safeguards, we may now consider a very few of the special and irreplaceable things which life-science can do for the citizen. To make its proper contribution life-science should be granted a continuous four-year place in the course of study of secondary schools.

Life-science can present the great fact of organic evolution. The origin by descent with modification of complex life, including man himself, and the kinship of all living things are included in this preeminent principle. In the center of all this we discover the principle of progress deep within ourselves; and the outlines of the rules and laws of that progress may and should become the common denominator of all thought about life.

Life-science presents the broad and humanly momentous principles of inheritance: How and why the offspring find repeated in themselves the characteristics of their ancestors; knowledge and understanding of differences or variation among offspring; the utilization of these principles in the improvement of races of animals and plants upon which human existence depends; and finally, the full realization that on the basis of their heredity no two men are exactly equal. Indeed, the very mechanisms by which we begin life, and the inner hereditary forces which attend our growth and development, assure us that all men are *un*equally endowed by nature. So significant are these well-established principles that we ask: For how long and to what extent dare communities, and their ever more complicated social and legal regulations, disregard this basic fact of the biologic inequalities of men? Here are questions for us all to decide; and how shall just and satisfactory decisions be obtained and enforced unless all know the facts upon which the decisions are made?

Life-science now presents the inspiring facts of the plasticity or modifiability of the growing organism. In much the same way, and using some of the same tools by which life-science has obtained control over many diseases, it has now made substantial beginnings in controlling the growth and attainments of plants, animals and of man himself. Depending upon which rays of light man selects to attend its growth the soy-bean can be made to become either a twining vine or a sturdy shrub; rats growing under all usual conditions may attain their usual size, but, by adding much more of certain vitamins to their food-supply throughout the growth period, man can now make them grow to twice their usual size; on man himself—throughout the civilized world—those little human dwarfs known as cretins are having inches added to their stature and new power added to their brains by the use of a secretion taken from the thyroid glands of an ox or sheep. Best of all, these and hundreds of kindred things are things always repeatable under the prescribed conditions—they are in no way at the caprice of magic or of wishful thinking. What a world of wealth and inspiration is this to the unspoiled youth—the future citizen—who thus learns of man's fast-growing power over even his own destiny!

Life-science—thanks to laboratory triumphs for almost each one of the last twenty years—now presents a handful of vitamins with which any youth may cure certain diseases; and better still

with these he can assure himself freedom from these diseases. This simply statable knowledge is needed by all, and all of it is particularly useful to the young. Shall we teach it in our schools? Or shall we leave it—like most other practical information about our natural environment—to the extra-curricular activities of groups such as the Boy Scouts.

Life-science presents the ever-present and pervasive fact of the struggle for existence with the consequent elimination of the unfit. The young citizen will learn that in our civilized communities the harsher aspects of that struggle are not present; that the individual no longer depends on his perfect bodily fitness, on the acuity of his senses, on the alertness of his mind, to survive and reproduce. He will know that this incidental denial of a rule of nature may or must have profound effects upon the future of man. He will find much food for fruitful thought in the dilemma that, unless we develop and use a far-reaching control over our own development, our high civilization will lead to the deterioration of the individual in his all-round fitness, both mental and physical; and that this retrogression—already in evidence—renders him correspondingly more and more dependent upon the community for his welfare. Emerging from these considerations, we find some assurance that with higher and higher communal evolution—with more and more intimate dependence of the individual upon the community—we should have greater and greater attention paid in our educational system to those subjects which have to do with the citizen's relations to and duties towards the community—duties such as discipline, ethics and loyalty to country and comrades.

Concluding this statement: The biologist would like to see a movement of our whole educational system away from the merely literary, doctrinaire, academic regions in which it is apt to be out of touch with the reality of biological fact and practical affairs. He would like to see men trained for citizenship and as comprehending members of a community. He would like to see a far more general recognition of the fact that the primary object of education is to make the individual able rather than learned. A learned individual may be, and often is, a stupid one. The brains of most of our youth are capable; let us stimulate and reward their continuous activity, and let us—in school and out of school—avoid giving them those easy assurances and sedatives which only put them to sleep.

THE COMPOSITION OF GLASS

By Dr. GEORGE W. MOREY
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Glass plays an important part in the researches of the Geophysical Laboratory of the Carnegie Institution of Washington. In our investigations on the genesis and evolution of the rocks formed by the freezing of a molten magma we study the melting and freezing of artificial minerals and their solubility in similarly constituted molten siliceous mixtures. The success of our studies is largely due to an experimental method of great power, which was developed at the Laboratory. It is called the quenching method and is based on that property of silicates which makes possible the formation of glasses.

Heating and Cooling Curves

When the Geophysical Laboratory's researches on silicates were begun, the only method available for the study of melting and freezing was that of heating and cooling curves. In that method, to determine a melting point the crystalline material is heated slowly, with continuous recording of the temperature. When melting begins, the absorption of the quantity of heat necessary to change the crystal to a liquid causes the temperature to fall behind that of the furnace and to remain approximately constant until melting is complete. That approximately constant temperature is taken as the melting point. Similarly, when the melted material is allowed to cool, at the beginning of freezing the setting free of the heat of transformation from the liquid to the crystalline condition causes the melt to cool less rapidly than the furnace and to remain at approximately constant temperature until freezing is complete; and again the constant temperature gives the freezing point.

That method works beautifully with metals and the common salts, but not with most silicates (Fig. 1). With those silicates of greatest interest it is impossible (Fig. 2). As a rule, when a molten silicate is cooled, instead of crystallizing at the freezing point the liquid persists unchanged, and in most cases can be cooled to ordinary temperature without freezing. It gradually becomes stiffer and stiffer, more and more viscous, finally reaching a condition of viscosity in which, for all practical purposes, it is rigid. In other words, it becomes a glass, and at ordinary temperature the glass will persist almost indefinitely. It is this characteristic of silicates that makes possible the glass industry.

Nevertheless, the glass has a natural freezing temperature usually within that elevated temperature range in which it is still soft enough to deform more or less easily. A little below the natural freezing temperature, the glass is inherently unstable, and by long-continued heating a little below its freezing point it can be transformed, in part or entirely, from the haphazard disorderly atomic distribution which characterizes the liquid into the orderly array which characterizes the crystal. The molten glass can be frozen to a crystalline aggregate, but the transformation is not prompt and inevitable, as is the case with a molten metal, but must be coaxed. Once developed, crystals can be redissolved only by heating above the freezing point of the mixture, and then they dissolve with comparative rapidity. The process of solution is dependable, and if the crystals do not dissolve, the sample being tested is below the

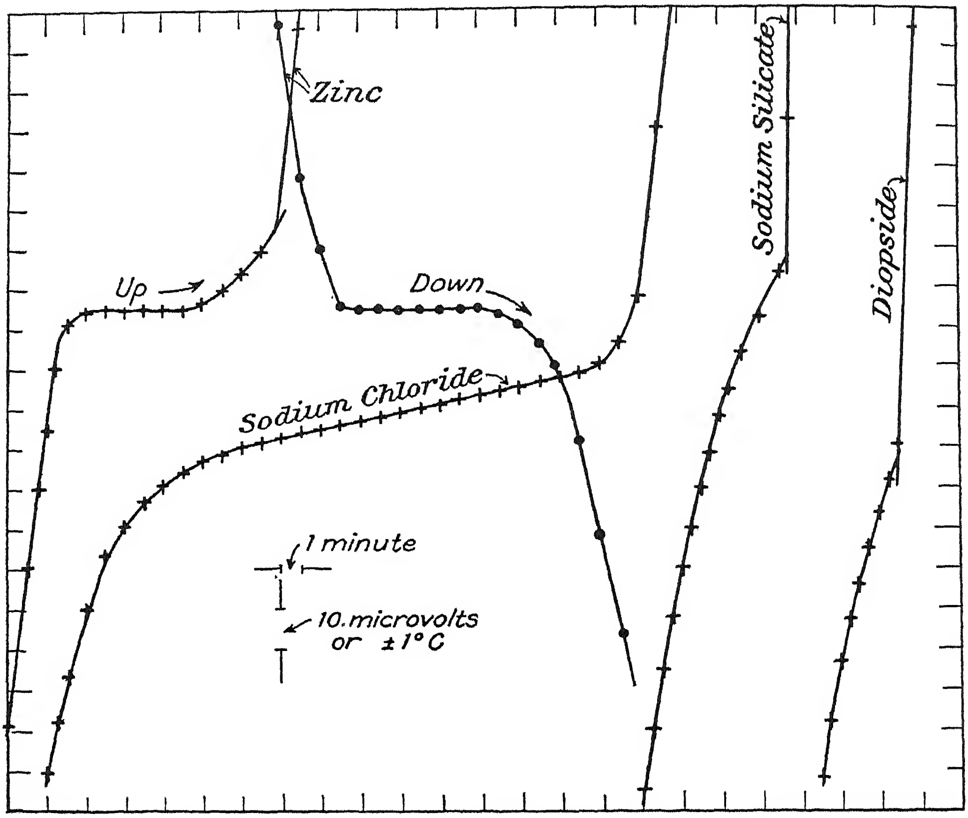


FIG. 1. SUBSTANCES WHICH CRYSTALLIZE EASILY

THE STUDY OF MELTING AND FREEZING BY MEANS OF HEATING AND COOLING CURVES. THESE CURVES ARE TYPICAL OF THESE OBTAINED WITH METALS, SALTS AND SILICATES WHICH CRYSTALLIZE EASILY.

freezing point, while if they dissolve, the temperature is above the freezing point.

The Quenching Method

It is by taking advantage of this characteristic of most silicates that the quenching method was developed. Mixtures of the component oxides which make up the minerals to be studied are melted to form homogeneous liquids. By a heat treatment at the requisite temperature these liquids are crystallized, to one pure mineral, or a mixture of two, three or more minerals, depending on the composition. Then small quantities of this crystalline mixture are held at various constant temperatures for a time long enough for the melting reactions to go to completion. The charge is then quickly cooled, or quenched, usually by dropping it into mercury.

Because of the characteristic sluggishness of the crystallization process in silicates, the cold charge is in exactly the same condition as at the temperature of the experiment, and examination with the microscope tells what that condition was. If the quenched charge is all glass, the experiment was above the melting or solution temperature of any of the crystalline compounds corresponding to that composition. If all crystalline, the temperature was below that of melting. If a mixture of glass with one kind of crystal, it indicates that partial melting had taken place, with solution of all but one

of the kinds of crystals. By systematically proceeding in this manner, the exact melting relations in a mixture of minerals of different proportions can be determined with precision, and that is the way in which we have worked out the relationships between crystals and liquid in a large number of systematically varied mixtures containing the rock-forming oxides, Na_2O, K_2O, CaO, MgO, Al_2O_3, FeO, Fe_2O_3 and SiO_2.

HISTORY OF GLASSMAKING

During the course of this work glasses of widely differing compositions have been prepared in the Laboratory. Most of these compositions have no resemblance to commercial glass types; and none of the new glass compositions are suitable for glass manufacture. The only compositions we have worked with that are suitable contain as their principal ingredients soda, lime and silica, and

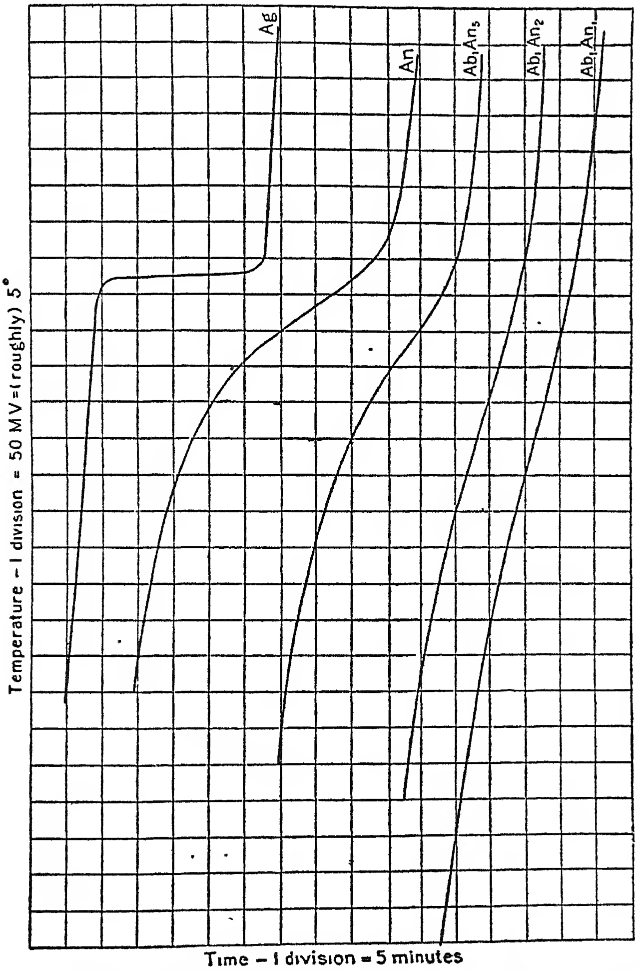


FIG. 2. SUBSTANCES WHICH DO NOT CRYSTALLIZE EASILY

THE STUDY OF MELTING AND FREEZING BY MEANS OF HEATING AND COOLING CURVES. THESE CURVES ARE TYPICAL OF THOSE OBTAINED WITH SILICATES WHICH DO NOT CRYSTALLIZE READILY. A HEATING CURVE WITH SILVER IS INCLUDED.

agree in all essentials with those compositions which have been used for glass from the beginning of its manufacture.

Man has known how to make glass ever since the earliest beginnings of civilization. The farther back the archeologist pushes the curtain of history, the farther back go the beginnings of glass manufacture. Glass was made in quantity by the Egyptians, and during that Golden Age of Egypt, the Eighteenth Dynasty, about 1500 B.C., glass manufacture was a well-established industry, and some of its products were of excellent quality. But it is probable that for the beginning of glass manufacture we must turn to Asia Minor. Beads of glass were plentiful in a cemetery at Ur, dating to 2450 B.C. Possibly the oldest piece of glass ever discovered was found by the 1931–32 expedition of the Oriental Institute of the University of Chicago at Tel Asram, a few miles northeast of Baghdad, dating to 2900 B.C.

From Asia Minor the industry was taken to Egypt, which remained its center until about the beginning of the Christian era. The glass factories of Alexandria were long famous, and from them the industry spread; back to Asia Minor, to China, to Constantinople, to Rome, thence to Germany, France, England and America. The first settlers in Jamestown, in 1607, brought with them workmen and material for establishing a glass factory, and the glass industry was thus the first to be transported to America. But the glass beads of Ur, the cosmetic jars of the queens of the Eighteenth Dynasty, the prized goblets of the Caesars, the beads made at Jamestown for trading with the Indians were all soda-lime glasses, of essentially the same composition as most of our windows and bottles to-day. The reason for this is to be found, not in the lack of enterprise of the glass manufacturer, but in the special requirements which must be met by a successful glass composition. That unique composition and condition of matter known as glass has been the heritage of mankind for five thousand years; but the reason why it is unique came as a by-product of the researches in silicate chemistry of the Geophysical Laboratory.

These reasons may be made clear by considering in some detail the researches which explained them. These dealt with the relations between the crystalline compounds formed of soda, lime and silica, and the liquids obtained by melting these ingredients or compounds. By soda is meant both the raw material used in manufacture, sodium carbonate, Na_2CO_3, which may be introduced either in the hydrated form of "washing soda" or the dehydrated "soda ash"; and sodium oxide, Na_2O, which is left in the glass after the reaction of the sodium carbonate with the silica during melting. By lime is meant both the raw material introduced as whiting or limestone, both calcium carbonate, $CaCO_3$, or burnt lime, CaO; and calcium oxide, CaO, which is left in the glass after reaction with silica during the melting process. The third and largest ingredient, silica, SiO_2, is common sand, whose widespread occurrence and availability in highly pure form at low cost make possible the cheapness of this incomparable material. I shall first discuss the mixture of silica and soda.

Study of Soda and Silica Mixture

Silica is dissolved by molten sodium carbonate, and when all the volatile material has been expelled the resulting mixture contains only sodium oxide, Na_2O, and silica, SiO_2. A large number of such mixtures, of systematically altered proportions of soda and silica, were studied by the quenching method, each at a number of temperatures, until each freezing point has been determined as closely as desired.

To enable the worker to keep track of, and correlate, the numerous experiments,

it is necessary to make a picture or map. In making such a map, the composition of mixtures of two substances is expressed graphically by a straight line, of limited length, whose two ends represent the two constituents (Fig. 3). Intermediate mixtures are represented by intermediate points on the line, and the proportion of the two components in any intermediate mixture is represented by the center of gravity, or balancing point, if the amounts of the two components were suspended from the respective ends. Then temperature can be represented by the vertical distance above this base line, and any point within the diagram will represent a mixture of a given composition at a given temperature.

The diagram (Fig. 3) also tells us just what will be the condition of each mixture at any temperature. The entire diagram is divided into two main portions by a discontinuous line, which represents the boundary between conditions of higher temperature under which the given mixture has all been melted to a liquid, and conditions under which it is partly or wholly frozen into crystals. Each part of the broken line represents compositions from which the same crystalline compound separates on freezing; and over the range of composition shown in Fig. 3 there are three different compounds, each of which possesses distinctive properties.

Compounds of Soda and Silica

On one side is sodium metasilicate, a compound of equal molecular proportions of soda and silica, which melts at 1089°. Sodium metasilicate crystallizes easily, so easily that it can not be obtained as a glass in lots larger than about an ounce. Nevertheless, on cooling it does not freeze promptly, but undercools so much that its freezing temperature can not be determined by the cooling-curve method. The melting point of the pure compound can be determined either by the method of heating curves, or by the method of quenching; but when the composition of the melt from which the compound is freezing is not the same as that of the metasilicate crystals the heating curves become difficult or impossible of

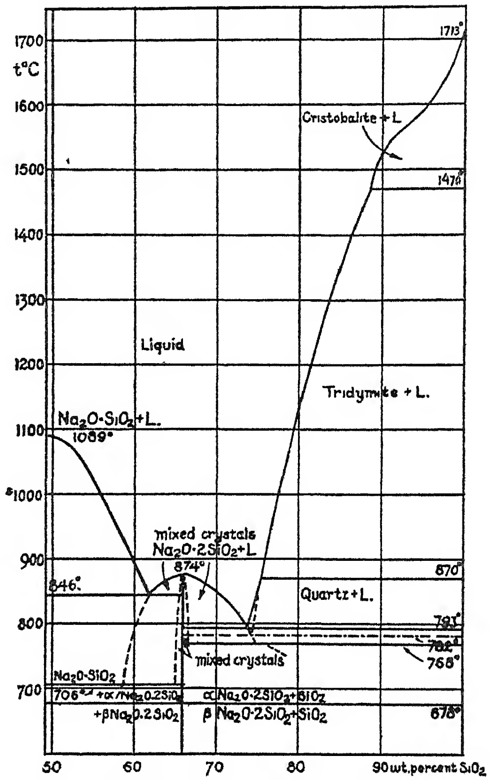


FIG. 3. MIXTURES OF SODA AND SILICA

Diagram showing the freezing points of mixtures of Na_2O and SiO_2 containing more than about 50 per cent. SiO_2. The composition, expressed as percentage by weight of SiO_2, is indicated along the base, and temperature by the distance above the base.

interpretation. Not so the quenching results. If a mixture containing 58 per cent. of SiO_2 is heated above 955°, glass only will be found on quenching; if heated a little below 955°, both glass and crystals will be found; and the nearer to 955° the fewer the crystals. By taking advantage of the tendency of silicates to form glass, the melting point can be determined as closely as desired.

Another compound formed between sodium oxide and silica is sodium disilicate, which is in sharp contrast to the metasilicate in the ease with which it crystallizes. Indeed, glass of this composition had been manufactured in ton lots for years without the compound ever having been obtained, and it remained unknown until our study of the melting relations of these mixtures. The explanation is to be found in the greater viscosity of the liquid at its freezing point. At 1100°, just above the melting point of sodium metasilicate, the viscosity of the liquid is about 14 poises.[1] At the same temperature the viscosity of a liquid of the composition of the disilicate is 550 poises. That 40-fold increase in viscosity at constant temperature is the result of the increased SiO_2-content. But the freezing point of sodium disilicate, 874°, is 215° below that of sodium metasilicate, and at that temperature the viscosity has increased to 26,000 poises. This large viscosity greatly interferes with the molecular rearrangements which must take place to transform the haphazard arrangement of atomic groups in the liquid to the orderly array characteristic of the crystal. Sodium disilicate does not crystallize readily, but cools to a glass.

Consider now the part of the diagram richer in silica. Pure silica, in the form of the mineral cristobalite, melts or freezes at 1713°. As soda is added, the freezing point falls, reaching its lowest value with the mixture containing 26.1 per cent. Na_2O, 73.9 per cent. SiO_2. The addition of a little over 26 per cent. of Na_2O has lowered the freezing point to 793°, a lowering of almost 1,000°. The enormous lowering of the freezing point of silica by alkali oxide is without a parallel. Because of the high content of silica, and the low temperature at the freezing point, the viscosity at the freezing point is about 200,000 poises, and a mixture of this composition invariably cools to a glass. It is exceedingly difficult to crystallize glass of this composition, even by extended heat treatment at the most favorable temperature.

Mixtures of soda and silica intermediate in composition between sodium disilicate and the mixture of lowest freezing point can be obtained as glass in ton lots, but such glasses are not suitable for the ordinary uses to which glass is put because they are soluble in water. The ordinary "water glass" used for a multitude of purposes, such as preserving eggs, as adhesive in the manufacture of corrugated paper and of emery wheels, and for the loading of silk, is prepared by dissolving a sodium silicate glass in water. Its manufacture is a major industry and requires the melting of thousands of tons of sodium silicate glass every year.

Melting Relations of Soda, Lime and Silica

Glass must be resistant to the action of water and weak acid, and something must be added to the sodium silicate to give it such resistance. The substance usually added is lime, CaO, because it gives an excellent product and is cheap. The melting relations of mixtures of the three ingredients, soda, lime and silica, have been determined, and from their study more has been learned about the conditions which make possible the manufacture of glass.

When lime, calcium oxide, is added to the various soda-silica mixtures, new

[1] By the viscosity of a liquid is meant that property by which a moving layer of liquid drags along adjacent layers. It is frequently measured by the tendency toward rotation transmitted through a liquid contained between two concentric cylinders, one of which is rotated. The unit of viscosity is named the poise. Water at its freezing point has a viscosity of about 0.02 poise; at ordinary temperatures, 0.01 poise. At ordinary temperatures olive oil has a viscosity of about one poise, castor oil, about 10 poises; and at 40° F. the viscosity of castor oil is about 33 poises.

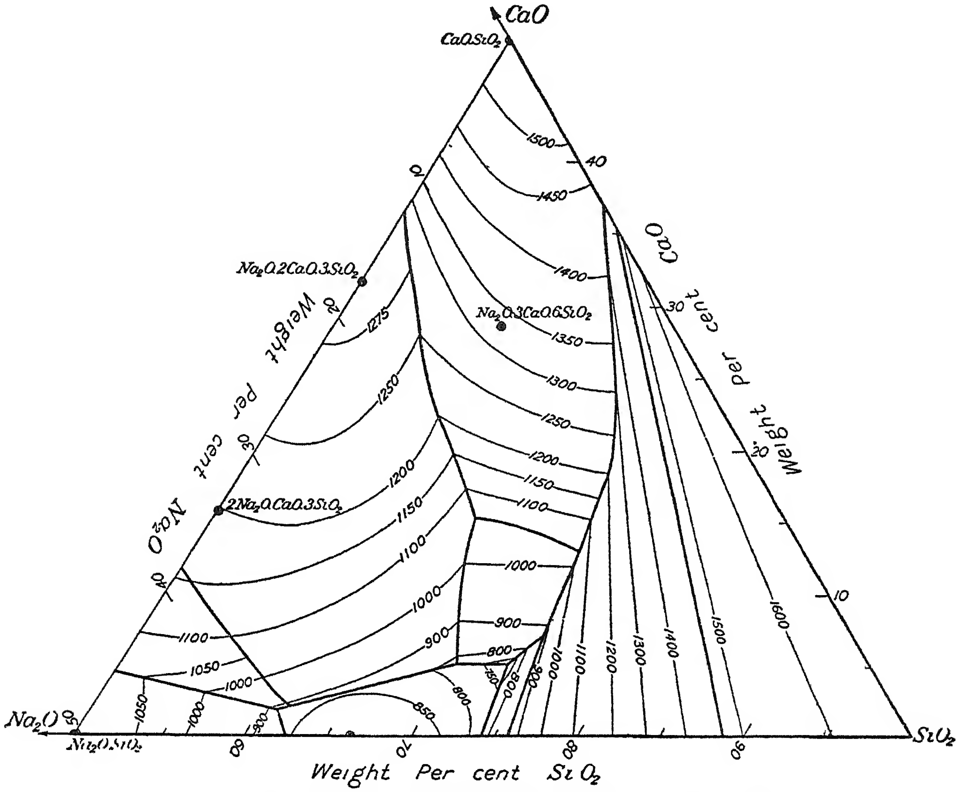


FIG. 4. MIXTURES OF SODA, LIME AND SILICA: ISOTHERMAL CURVES

DIAGRAM SHOWING THE LINES OF CONSTANT FREEZING POINT IN MIXTURES OF Na_2O, CaO AND SiO_2 CONTAINING MORE THAN ABOUT 50 PER CENT. SiO_2. THE ISOTHERMAL CURVES WHICH GIVE THE COMPOSITIONS OF MIXTURES HAVING THE SAME FREEZING POINTS FORM SEVERAL FAMILIES OF CURVES, EACH FAMILY CHARACTERIZED BY THE SAME CRYSTALLINE COMPOUND. THE COMPOSITION REGION THUS OUTLINED IS CALLED THE "FIELD" OF THE COMPOUND.

compounds are formed. Calcium oxide forms with silica a compound, calcium metasilicate,

$$CaO\ SiO_2$$

which is found in nature as the mineral wollastonite. With sodium metasilicate, calcium metasilicate forms two compounds,

$$2Na_2O \cdot CaO\ 3SiO_2$$

and

$$Na_2O\ 2CaO\ 3SiO_2.$$

These compounds are shown in Figs. 4 and 5, diagrams which show the melting relations of mixtures of the three ingredients, just as Fig. 3 shows those of the two components, soda and silica. The base line represents mixtures of sodium metasilicate,

$$Na_2O\ SiO_2,$$

and silica; the right-hand side, of calcium metasilicate,

$$CaO \cdot SiO_2$$

and silica; and the left side, of sodium metasilicate and calcium metasilicate. Fig. 4 shows clearly the compositions of the compounds and the composition regions from which they separate as crystals when the melt is cooled. For example, the compositions of the two metasilicate compounds,

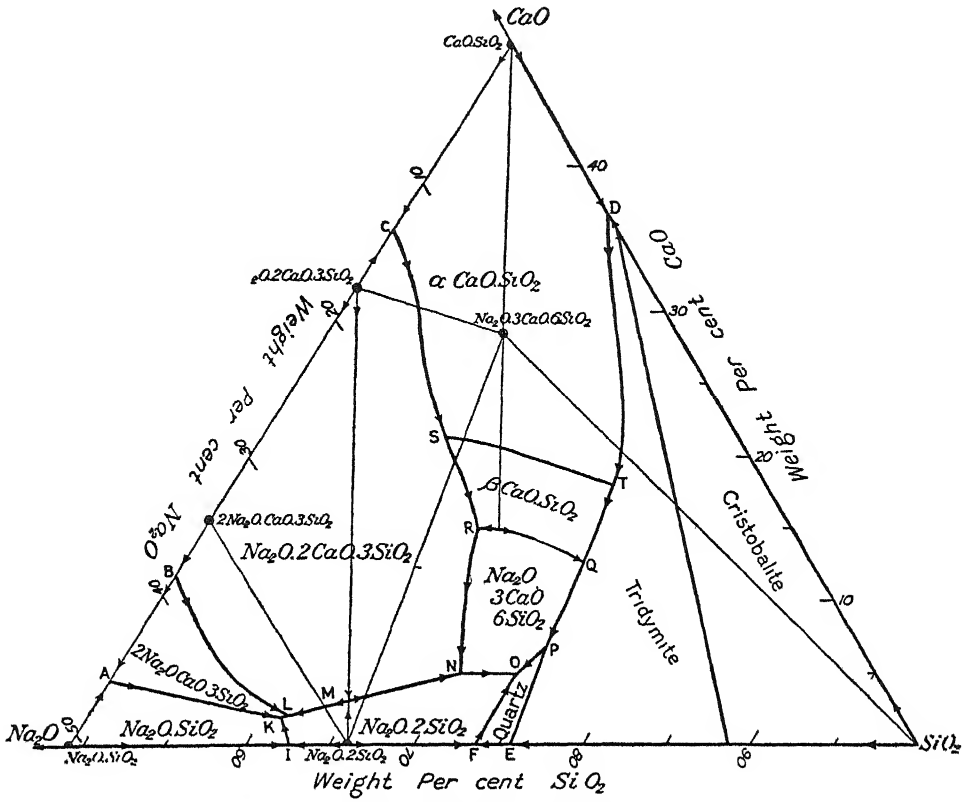


FIG. 5. MIXTURES OF SODA, LIME AND SILICA: BOUNDARY CURVES

DIAGRAM SHOWING THE BOUNDARIES BETWEEN THE FIELDS OF THE VARIOUS COMPOUNDS FORMED FROM MIXTURES OF Na_2O, CaO AND SiO_2 CONTAINING MORE THAN ABOUT 50 PER CENT. SiO_2. THE ARROWS ON THE BOUNDARIES BETWEEN THE FIELDS INDICATE FALLING TEMPERATURES.

$$2Na_2O\ CaO \cdot 3SiO_2$$

and

$$Na_2O \cdot 2CaO\ 3SiO_2,$$

are shown on the side

$$Na_2O\ SiO_2\text{-}CaO \cdot SiO_2;$$

their respective fields (Fig. 5) are *ABLK* and *BCSRNML.*

Mixtures of calcium and sodium metasilicates are not suitable for glass manufacture because they pass so readily into the crystalline condition that they can not be made on a manufacturing scale, although they can be made in small quantity. Also, when they are rich in sodium metasilicate they are too susceptible to attack by water. This is true of all mixtures which lie to the left of the line joining

$$Na_2O\ 2SiO_2$$

with

$$Na_2O \cdot 2CaO \cdot 3SiO_2,$$

and these mixtures will not be further considered. To obtain a resistant glass more silica must be added, and such addition lowers the melting point.

When more silica was added to sodium metasilicate a compound, sodium disilicate, was formed, which has a low melting point, and is readily obtained as glass. No such compound is formed with calcium metasilicate, which melts at 1540°. Also, the lowest melting mixture of lime and silica melts at a high tem-

perature, 1436°, and crystallizes readily. Sodium silicate must be added. When the sodium silicate added to calcium metasilicate is sodium disilicate, or a sodium silicate mixture containing a larger proportion of silica, a new compound makes its appearance. This compound has the composition

$$Na_2O \cdot 3CaO \cdot 6SiO_2$$

and, because of its important part in the crystallization or devitrification of the ordinary soda-lime glass, it has been named "devitrite."

The composition of devitrite is such that it may be regarded as made up of calcium metasilicate and the lowest melting mixture of soda and silica. It has characteristic properties which help to explain the formation of glass. When the pure compound is heated, it does not remain homogeneous until its melting point is reached, then melt to form a liquid of the same composition as the crystals. Instead, it begins to melt at a much lower temperature, 1060°, with formation of crystals of wollastonite and a liquid containing much more sodium silicate. This liquid is on the line *RQ* of Fig. 5. Because of this peculiar type of melting it follows that the melts from which devitrite crystallizes, shown in the area *NRQPO* of Fig. 5, are richer in sodium silicate, and they are low melting liquids. They melt lower than any other mixtures of the three components; and the lowest melting of all is that represented by the point *O*, 725°. They are very different in composition from the crystals which should separate; and to form these crystals there must be much molecular movement. But the glass at point *O* has the enormous viscosity of 9,000,000 poises, consequently molecular movement is slow and crystallization ordinarily does not take place. Every composition within the devitrite field is a possible commercial glass composition, and most commercial glasses are within this composition range, in so far as they are pure soda-lime glasses.

We have seen, then, that the region of commercial glass compositions is essentially that of the compound,

$$Na_2O \ 3CaO \cdot 6SiO_2,$$

and that the temperatures in this region range from 1060° to 725°, and we have the answer to why glass behaves like glass. Mixtures within this area are above their freezing temperatures throughout their working range. Glass must be subjected to various shaping operations while in a not too viscous condition, and if the freezing point is within the temperature range within which it must be worked, crystallization is almost certain. But because of their low freezing points, glasses in this area become viscous enough for working while still too hot to freeze, and by the time the freezing point is reached the glass is so viscous that crystallization can be induced only by special heat treatment. But let the composition depart only a few per cent. from a restricted field, and this is no longer true. As soon as the glass enters the field of silica, of calcium metasilicate or of

$$Na_2O \cdot 2CaO \cdot 3SiO_2,$$

the temperature increases rapidly and crystallization takes place much more readily. Hence the glassmaker must keep his compositions within narrow limits.

He is aided, however, by another factor; he is never working with pure soda-lime glasses, even though he may call them such, but always with glasses containing significant amounts of other constituents, which are introduced incidentally either as impurities, in the ingredients, or of the containers in which they are melted or which are introduced deliberately. The effect of each of these impurities is to lower the melting point. For example, replacement of one per

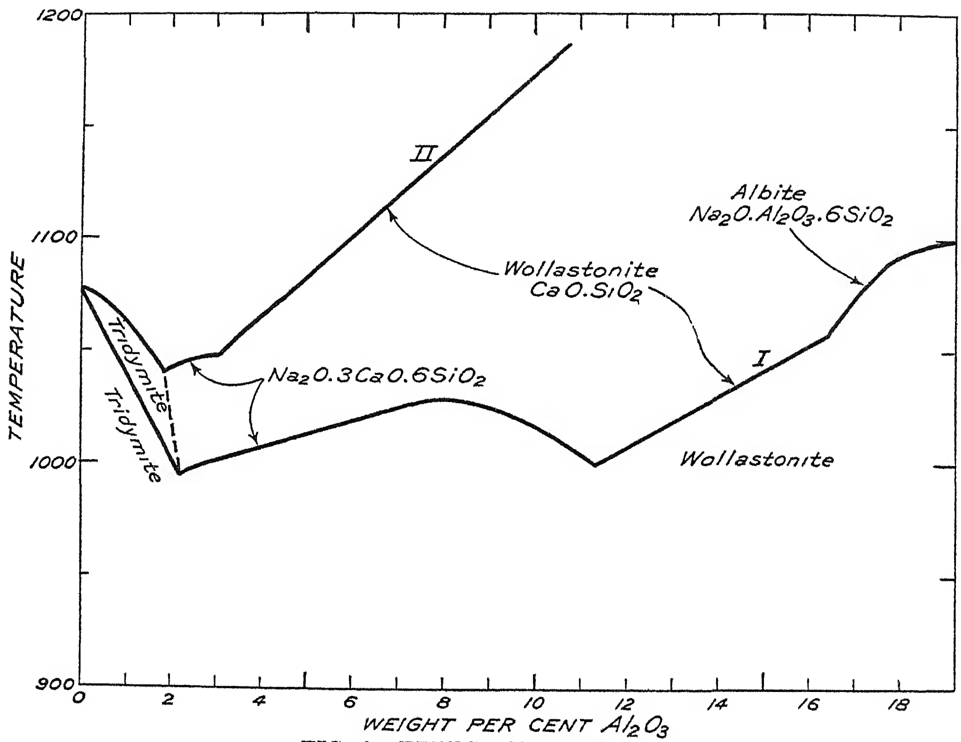


FIG. 6. EFFECT OF ALUMINA

THE EFFECT OF ALUMINA ON THE FREEZING TEMPERATURE OF A SODA-LIME-SILICA GLASS CONTAINING 11 PER CENT. CaO AND 74.7 PER CENT. SiO_2. CURVE I SHOWS THE EFFECT OF REPLACING LIME BY ALUMINA, AND CURVE II THE EFFECT OF ADDING ALUMINA TO THE GLASS.

cent. of lime by alumina lowers the melting point almost 100° (Fig. 6).

The story of the discovery of the advantage to be gained by the addition of alumina is an interesting one. Back in the eighties it was a matter of common knowledge that glass made in the Thuringian Forest was superior for glass-blowing, because under treatment which would devitrify an ordinary soda-lime glass it remained clear and transparent, and the difference was ascribed to some secret formula. But an investigation showed that the sand used contained almost 4 per cent. of alumina and that addition of alumina to the usual batches greatly improved the product. We can explain this now: the alumina lowered the melting point and brought the glass into the field of the

$$Na_2O \cdot 3CaO \cdot 6SiO_2$$

compound, which is characterized by small tendency toward crystallization.

The effect of other oxides which may be considered as accidental impurities is similar. Some magnesia, MgO, is usually present, if only as the result of corrosion of the clay container in which the glass is melted, but small amounts of magnesia have a favorable effect in lowering the liquidus temperature (Fig. 7). In the United States it is a common practice to introduce magnesia by the use of dolomitic limestone. Iron oxide has a marked effect in lowering the freezing point, and it was present in most of the older glassware, in amounts which would not be tolerated to-day, except when the color it gives is definitely wanted. Boric oxide is often added, to increase the speed of melting, the chemical durability, the brilliance

and the strength. It has a favorable effect in lowering the melting temperature.

Many glasses contain part or all of their alkali as potash, K_2O, but its use is limited by its higher cost. The glasses formed are more difficult to crystallize than the soda glasses, which circumstance is probably to be ascribed largely to the greater viscosity of the potash glasses, although the larger number of dissociating compounds, with consequent increasing molecular complexity, undoubtedly plays an important part. The "Bohemian" glass used for combustion tubing, which must withstand a high temperature, is a potash glass. The addition of potash to a soda glass diminishes the tendency toward devitrification, increases the viscosity and renders the glass more resistant to weathering.

Types of Manufactured Glass

Most of the glass manufactured is essentially of the soda-lime-silica type, modified by the inclusion of small percentages of other oxides; and the major uses to which glass is put, including windows, automobile glazing, bottles, jars, table ware and electric light bulbs, take a glass of this type. The various types of glass used for chemical ware and laboratory tubing were formerly exclusively from this same type. The ordinary "soft" glass was a soda-lime glass, the inferior grades tending to be low in lime, high in soda, which placed them rather near the lower portion of the

$$Na_2O \cdot 2CaO \cdot 3SiO_2$$

field, and containing little alumina. The better grades contained Al_2O_3 and were nearer the boundary between

$$Na_2O \cdot 3CaO \cdot 6SiO_2$$

and silica. From this the composition ranged from those which were improved by the inclusion of some MgO, K_2O, B_2O_3 or zinc oxide, ZnO, to those, such as the Jena Geräte, in which all these oxides were present. All these types are to be considered as derived from the ordinary soda-lime composition by the addition and substitution of different oxides for the purpose of securing greater resistance to weathering, and a lowered freezing temperature.

These older types of chemical ware have been largely superseded by Pyrex resistant glass, which is of a different type, not to be regarded as derived from the ordinary soda-lime glass. Rather, it is a glass in which the melting point of the silica is lowered by the addition of boric oxide, B_2O_3, and, in smaller amount, alumina, Al_2O_3, with only the smallest possible amount of alkali. It is intrinsically superior to corrosion and to breakage from heat shock, but is more difficult to manufacture and work.

The 200-inch telescope could not have been made if such a superior glass were not available. The protracted heat treatment necessary to cool that enormous mass of glass without introducing strains

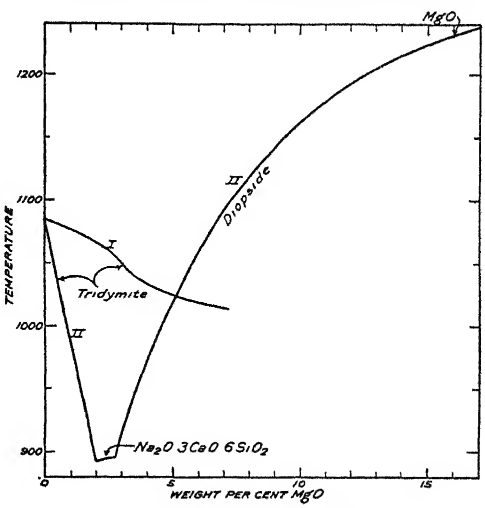


FIG. 7. EFFECT OF MAGNESIA

The effect of magnesia on the freezing temperature of a soda-lime-silica glass containing 11 per cent. CaO and 74.7 per cent. SiO_2. Curve I shows the effect of replacing lime by magnesia, and Curve II the effect of adding magnesia to the glass.

PERCENTAGE COMPOSITION OF SOME REPRESENTATIVE GLASSES

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Silica	SiO_2	67.82	63.86	65.03	65.95	68.0	74.16	72.5	72.68	71.76	64.7	66.90	79.57	80.75	70.4	71.34	34.5	59 3	45 64	28 4	75 52
Boric oxide	B_2O_3										10.9	7 22		12.00	7.4		10.1				
Sodium oxide	Na_2O	13 71	22.66	17.37	20.30	22.0	15.08	15.9	13.17	12 65	7.5	1.25	0.66	4.10	5.3	13.42		5 0	1.77		3 92
Potassium oxide ...	K_2O	2 31	0.80	1 68	0.96			0.5			0.37	2 40	11.60	0 10	14.5	0.10		8 0	8 66	2.5	3 63
Calcium oxide	CaO	4 03	7.86	5.65	6 89	7 2	4.64	4.9	12 95	11.55	0 63	7.94	7 80	0 30	2 0	12.51			0 50		0.78
Magnesium oxide ..	MgO	2 30	4.18	2.52	1.37		3.41	3.5		2.41	0.21	0 61	0 11								0 10
Barium oxide	BaO											7.27					42 0				
Zinc oxide	ZnO										10 9						7.8				
Lead oxide	PbO			0.19														27.5	43.45	69.0	
Alumina	Al_2O_3	4 38	0.65	2 13	2.49	3.1	1.25	1.6	0.50	0 82	4.2	6.38	0 32	2 20		0 09	5.0		0.03		14.11
Ferric oxide	Fe_2O_3	1.08	0 67	0.97	0 28				0 07	0.10	0 25	0 22	0 04								1.74
Sulfur trioxide	SO_3	0.98		1.70	1.08				0.44	0.47											
Manganese oxide ..	Mn_2O_3	1.12	trace	0.65	0.97						0 01				0.1		0 1				

1 Egyptian glass from Thebes, about 1500 B C Opaque, dark blue, also contains 1.96 per cent. copper oxide, CuO.
2. Egyptian glass from Tell el Amarna, about 1400 B.C. Opaque, dark colored
3. Assyrian-Babylonian glass from Nippur, about 1400 B.C. Dark blue. Also contains 1 94 per cent copper oxide, CuO, and 0.93 per cent. cobalt oxide, CoO. This is the only known occurrence of cobalt oxide in antique glass.
4 Egyptian glass from Elephantine, about 100 B.C. colorless.
5. Inferior glass made for Christmas tree ornaments
6 Bottle glass.
7 Electric light bulb glass.
8 Polished plate glass
9 Modern window glass
10. Laboratory glass, Jena Geräte. Also contains 0 14 per cent arsenic oxide As_2O_5.
11 Laboratory glass, Jena combustion
12 Laboratory glass, Kavalier.
13. Laboratory glass, Pyrex chemical resistant
14. Optical glass, borosilicate crown Also contains 0.2 per cent As_2O_5
15 Optical glass, spectacle crown. Also contains 0 9 per cent , As_2O_5.
16. Optical glass, dense barium crown Also contains 0.5 per cent , As_2O_5.
17. Optical glass, light flint. Practically this same glass is used for heavy cut glass, for some tubing, and some electric light bulbs. Also contains 0 2 per cent As_2O_5.
18 Optical glass, medium flint. Also contains 0 22 per cent. As_2O_5
19 Optical glass Extra dense flint Also contains 0 1 per cent As_2O_5.
20 Obsidian glass from Obsidian Cliff, Yellowstone National Park. Also contains 0.08 per cent FeO

from unequal heat distribution would inevitably have devitrified an ordinary glass. The improved Pyrex used is especially resistant to devitrification, and the success of the Corning Glass Works in making this great disk is in part due to the superior glass which they developed for the purpose.

The optical glasses are a group important in their use in instruments but insignificant in their tonnage and total commercial value. They are all derived essentially from the same general type. Many optical glasses of the crown type are essentially the same as ordinary window glass, except that they possess the quality characteristic of all optical glasses of a physical perfection resulting from freedom from bubbles and inhomogeneity. Other similar glasses contain notable quantities of K_2O replacing Na_2O, and of B_2O_3 replacing SiO_2, in quantity up to, and sometimes exceeding, 10 per cent., giving rise to the borosilicate crowns.

An important series of glasses are the optical "flints," which contain lead oxide, PbO. They range from light flints containing 25 to 30 per cent. of PbO, and essentially the same as the lead glass formerly extensively used for blowpipe work, for lamp bulbs and for cut glass, up to extra dense flints containing as high as 80 per cent. of PbO. The optical flints usually contain K_2O as the only alkali.

Another important group of optical glasses are the barium crowns, characterized by the presence of barium oxide, BaO, in place of lime, but still essentially of the same general composition, and owing their important qualities to the high molecular weight of barium oxide. The optical glasses are for special purposes, and as a class are not suitable for most of the uses to which glass is put, by reason of too great susceptibility to weathering, difficulty in manufacture or high cost.

Non-Commercial Types

Those compositions which have been hit on for commercial glasses have the common characteristic that they exhibit a great reluctance to pass from the liquid to a crystalline condition even under the most favorable circumstances, a characteristic possessed in a less or even in a greater degree by many substances wholly unsuitable for practical use. Many organic substances fall in this category, of which glucose solutions may be taken as example. Beryllium fluoride can be obtained as glass. Alum and some complex sulfates can be quenched to the glassy form. Phosphates are well-known glass formers, and, indeed, the so-called meta- and pyrophosphoric acids are known only in the glassy condition. Boric oxide, B_2O_3, has never been obtained in any but the glassy condition. None of these is suitable for commercial uses because they are too easily decomposed by water.

Glass made from silica itself possesses in the highest degree the necessary properties of freedom from devitrification and resistance to weathering, and if it were not so difficult to melt it would be the most suitable material for most of the uses to which glass is put. The melting point of the high temperature form of silica is 1713°, and at its melting point it is so exceedingly viscous that special and expensive treatment is necessary to free it from bubbles and obtain a clear transparent glass. The resulting cost of manufacture is prohibitive, and other oxides must be added to lower the melting point and viscosity. In addition there are some uses in which the modification of properties obtained by the incorporation of other oxides is essential.

Natural silicate glasses are known, most of which can be grouped under the term obsidian. The obsidian cliffs of Yellowstone Park are enormous masses

of this volcanic glass, and it is widely distributed over the surface of the earth. It was highly prized by people of Stone Age culture, and worked by chipping into axes, spear and arrow heads and even into knives and razors. In composition it may be considered as a mixture of alkali feldspar and silica, and in the Laboratory we have studied such mixtures.

The alkali feldspars differ in composition from ordinary glass chiefly in their containing alumina instead of lime. The soda feldspar, albite, has the composition,

$$Na_2O\ Al_2O_3\ 6SiO_2;$$

and if the alumina were replaced by lime, giving Na_2O, CaO, $6SiO_2$, the resulting composition would be near the most favorable glass field. But natural obsidian can not be imitated by the glass manufacturer, and the alkali feldspar glasses are not suitable for commercial glass, because of their enormous viscosity. The soda feldspar, albite, has a true melting point at 1122°, and the potash feldspar, orthoclase, melts with decomposition at 1170°. But at 1200° the albite glass has a viscosity of 10 million poises, and orthoclase glass a viscosity of 300 million poises. It is necessary that a successful glass composition be fluid enough to melt readily at a temperature accessible in industrial practice.

The feldspar glasses will not crystallize, but other mineral glasses we have made in the Laboratory crystallize too readily. They can only be obtained by the quenching method and thus are not suitable for commercial glass. Indeed, of the whole range of possible silicate compositions, the only mixtures which are fluid enough at an industrially accessible temperature to be melted on a commercial scale, viscous enough to be worked at a temperature above their freezing points, and so viscous at their freezing points that they can not devitrify, are those soda-lime-silica glasses in and near the field of the compound,

$$Na_2O\cdot 3CaO\ 6SiO_2,$$

the compositions which always have been used for commercial glass.

Summary

That unique composition of matter which is commercial glass has been known to mankind for at least five thousand years. For these many centuries man has made glass. Its manufacture first was a primitive art. Then it became an industry, an industry which was a small-scale personal triumph of a skilled craftsman working with miserable equipment and bound by the spell of tradition. Now it is a mighty mechanized industry, controlled by applied scientific knowledge. But the reason why this composition of matter is the only one possible for a commercial glass remained a mystery throughout the centuries until it was discovered by the Geophysical Laboratory as an incidental by-product of its researches on the chemistry of the silicates.

PRISONERS OF DARKNESS

By Dr. STANTON C. CRAWFORD
PROFESSOR OF BIOLOGY, UNIVERSITY OF PITTSBURGH

Animals that live most of their active lives in the darkness of night and shun the light seem to be prisoners of that darkness in a very real sense. Some bond holds them within the shadows. Striking examples are afforded by termites, woodboring beetles, deer-mice and opossums. In addition to the citizens of night there are those of dawn and dusk, which inhabit a zone of half light. Insects accustomed to appear at a certain time as twilight falls may appear earlier than usual on cloudy evenings. Such instances could be recounted in great number.

An apparent explanation of these habits is that the various animals seem to be attuned to certain ranges of intensity of light. For each species there is an optimum light range, which the members of the group seek as a setting for the normal activities of life. The degree of intensity is supposedly determined by the visual sense. Thus, most butterflies are attuned to a higher intensity of light than are many moths. Bright sunlight attracts the one, repels the other. The tawny Monarch flits over the meadows, visiting milkweed blossoms, or floats high over city streets, while the nocturnal moth clings to the bark of a shaded treetrunk, which it often closely resembles. But let darkness fall, and the butterfly hangs motionless on a leaf. The weak flame of a candle, so dim a light as not to stimulate the butterfly at all, serves as an irresistible and fatal attraction to the moth. Light traps are now employed to catch such orchard pests as codling moths, bud moths, leaf-rollers, cutworm moths and other insects. The flight of the moth toward the lamp is so nearly automatic that it can not save itself. Nature provides no protection for such situations, because the natural lights which the insect would encounter at night, those of the heavenly bodies and reflections of the same from earthly objects, afford no possibility of harm.

The moth of nocturnal species lives a life of oblivion in comparison with his brilliant and conspicuous relatives which are admired in the brightness of sunlight. Some beautifully colored moths seldom would be seen by man were they not drawn from the cool black shadows to the unnatural glow of artificial lights. Within closely related groups of moths there are delicately graded degrees of sensitivity to light. In the American silkworm group, Phil and Nellie Rau report that *Cecropias* fly during the hour just before and at dawn, while *Cynthia* and *Polyphemus* moths fly before midnight as well as at dawn. *Prometheas* on the other hand fly in the late afternoon.

Other conditions, such as increased humidity, lowered air temperature, reduced air motion and decreased rate of evaporation, are characteristic of the night, and these items have great importance for living things. Nevertheless, at least for the vertebrates, the absence of light looms as the most significant factor of the nocturnal environment.

Animals which from conscious or unconscious beginnings have now arrived at a nocturnal or crepuscular habit undoubtedly find advantage in carrying on the more active phases of existence under cover of darkness or in dim light. The

more likely explanations that present themselves to man's mind may or may not constitute sufficient reasons for the adoption of the nocturnal habit. Further, it would not be supposed that, except in the higher mammals, the night time is consciously chosen on account of any of these advantages. It might be considered that these benefits associated with nocturnal living were factors that in some way and over a long period of time caused various races to avoid light. Now inherent in these forms of life, the propensity for nocturnal activity expresses itself when the favored environmental factors recur in nightly rhythm.

The most evident advantages of the nocturnal habit are four. First might be named the avoidance of natural enemies that are active in daylight. Harvestmen, spiders, millipedes, crickets, roaches, moths and ants would in many instances be sought as food during the day by birds and reptiles as well as by insectivorous mammals. Toads and frogs would be eaten by snakes, by such birds as herons and hawks and by some mammals. Rats and mice would find many enemies among mammals, birds and reptiles. Bats would be pounced upon by hawks.

This avoidance of enemies also seems of possible advantage in the case of animals popularly supposed to be protected by concealing and imitative color or configuration, which nevertheless would form part of the diet of daytime animals. The walking-sticks and mantids, which in outline, texture and coloration so closely resemble leaves and twigs, do not always escape the notice of day birds.

Further, there is greater safety at night for the feeding of herbivorous animals. Thus, there are the fruitbats, great Chiropterans with a wing-spread of two or three feet, which hang themselves up to feed on tropical fruits. Porcupines, beavers and rabbits feed in comparative safety. Agoutis feed on fallen nuts and fruits at night. Defenseless, they depend on the darkness for concealment and on speed for escape. The capybara, a huge guinea pig several feet in length, feeds on swamp plants along the Brazilian river banks after dusk. To their respective streams also come the bush cow or tapir, the elephant and rhinoceros. The deer and other grazing animals can feed unseen at night, keeping the head down with comparative safety. Animals engaged in such feeding activities would be especially vulnerable to their natural enemies in daylight.

A second advantage would seem to be afforded through easier location and acquirement of the preferred food at night. This benefit may be ascribed variously to the invisibility of the hunter, the plentifulness at night of the intended food animals or the greater ease of detecting victims by the sense of smell. Odors remain longer in the air at night, due to greater humidity and the relative absence of upward air currents. Further, if the prospective victims are themselves typical daytime forms, they are more subject to attack at night on account of sleep or its equivalent or their poorer adaptation for successful nocturnal activity. This advantage for the nocturnal hunter may be realized by carnivorous animals such as the scorpions, tarantulas, spiders, sluggish snakes, owls, goatsuckers, raccoons and cats. Also, scavengers and general feeders may be able to seek food with more ease at night, due to better conditions for the use of the olfactory sense. Beetles, millipedes, 'roaches and the vertebrate opossums, kinkajous and armadillos, for example, might be considered as coming under this heading.

Successful avoidance of evaporation from the body surface may be named as a third advantage. Animals that on

account of the nature of their external covering would suffer from excessive evaporation through daytime activity, and would conceivably benefit from the nocturnal habit include earthworms, snails, cockroaches, mosquitoes, termites, salamanders, toads and treefrogs. Park and his colleagues reported that many insects of Ohio forests increase nocturnal activity with increase of relative humidity, decrease of air temperature and rate of evaporation.

A last major advantage is doubtless found in better conditions for communication at night. Sounds produced have less competition, odors travel farther and are apparently stronger in the damp air. Light-producing organs are of value at night and useless by day.

Some animals seem to benefit in two or three of these ways. In any one species, the reasons applicable can only be conjectured. Not all those active at night can be seriously placed under any heading. Thus the fact that the longhorn grasshoppers are in some species nocturnal, in some day-living, while practically all are apparently protectively colored and all live in the same general environment is difficult to explain. Along with almost any species active at night for any apparent reason can be found a closely related form not active at night, yet exposed to the same conditions of life. The problem is hence a very complex one, inviting extensive and detailed study.

When we seek to determine the adaptations exhibited by groups active at night, we encounter much uncertainty. Such differences in sense organs as exist between nocturnal and daytime forms of close relationship are differences of degree rather than of kind. There are a few definite adaptations in the way of light, sound and scent production. Nevertheless, with the possible exceptions of luminescence and some features of vision, there is observed no modification which might not be fully as useful by day as by night. Our judgment is that the extreme development of some of these specializations of form and function is not so necessary for successful living by day. The species named might be capable of successful nocturnal existence without any or all of the supposedly appropriate modifications which they exhibit. The crucial point of development of each sense necessary for the successful nocturnal activity of a given animal species would be very difficult to determine, especially since the senses are not employed singly so often as collectively.

Further, it would be difficult to list the various senses in the order of their relative usefulness at night. The sense of smell is probably of greatest importance, and that of sight might be named last, but undoubtedly this arrangement would be questioned. It must be remembered that our ideas in regard to the sensations of animals other than ourselves, of invertebrates particularly, are only inferences from our own sensory experiences. It is likely that they are often inadequate and erroneous. We can never be sure that lower animals experience sensations in the same way that we do, even though perceptory organs of seeming adequacy are known to exist. However, a number of generalizations may be made about these sensory functions.

The sense of smell may be suspected of having at least four uses at night. First, it assists in the congregating of individuals of the same species and in following trails. Invertebrates employing the sense for these purposes include along with others the termites and ants, among which the activity of the whole colony is apparently directed chiefly by scent and odor. Vertebrates that could be named in this connection are opossums, muskrats, beavers, raccoons, cats,

porcupines, armadillos, bears and deer. It has been suggested that the oil from the preen gland of birds when spread on the feathers may aid in recognition of individuals amid the darkness of night or the shadows of dense plant growth.

Secondly, this olfactory sense functions in sex attraction, by means of "alluring glands." Females of many species of moths and beetles emit an odor that attracts the males, often in large numbers. The vertebrate alligators, cats, peccaries and deer along with many others would come in this category.

Thirdly, this sense functions in the location of food. Animals in which the olfactory sense is depended upon heavily for this purpose are the roaches, beetles, moths, mosquitoes and ants; armadillos, porcupines, raccoons, cats, bears, foxes, weasels, mice, rats, opossums, and of course many others.

Fourthly, it functions in the detection of enemies and friends. This is apparently an important use of the sense in such vertebrate forms as the bear, deer, antelope and tapir, and many invertebrate groups.

The sense of taste, which is closely associated with the olfactory sense, is very generally developed throughout the groups of non-aquatic invertebrates. No greater development of this sense would be expected in nocturnal animals than in their daytime relatives. Perhaps our ideas on this point do not coincide with the actual situation, however, since the sense is so much more highly developed in ants, flies, etc., than in ourselves, and hence perhaps much more significant in their lives than in ours. In various insects, organs of taste have been located on antennal and leg surfaces. Such equipment would seem to give the sense special usefulness at night for finding and inspecting food, if species possessing such structures are active in the dark. Organs of taste certainly have large usefulness at night for inspecting food that can not be seen.

Perhaps the main distinction between the senses of smell and taste is that if the end organs actually come in contact with the food they are to be considered gustatory; if they do not, they are to be considered olfactory. Both of these senses, when resident in antennal structures, are closely associated with that of touch. There would thus be a contact-chemical sense of unified character. Nocturnal insects, which obviously have delicate antennae on which they depend heavily for sensory experience, include centipedes, crickets, walkingsticks, roaches, termites and ants. They are probably just as important in other insects whose antennal equipment is not so apparently depended upon.

Organs of touch are of value at night in moving about, in inspecting food or other objects encountered and in perceiving vibrations. This last faculty passes into that of hearing. Among the invertebrates many sensitive and elaborate organs of touch are found. Delicate tactile hairs are a device frequently employed. Among the vertebrates, aside from the general sensitivity of the skin, we find such special developments as the "whiskers" of rodents and various other mammals, the delicate muzzle of the deer and the very sensitive organs of the nose and wings of the bat. The facial pits of the pit-vipers are reported to function in the perception of air vibrations. All these structures are devices for stimulating nerve terminations.

Closely associated with the tactile sense is sensitivity to temperature. Temperature affects the degree of activity of many animals which are abroad at night, functioning in correlation with humidity and air motion. Insects, with a large surface-to-volume ratio, have a special problem with reference to temperature changes.

The sense of hearing is closely allied to

that of touch, particularly among the invertebrates. Sound production and reception is often a major means of communication between members of the same species at night as well as by day, and is important in the detection of approaching enemies or victims, as the case may be. Sound-making serves to frighten away enemies, to warn others of their approach, to attract and woo mates, to communicate items of information. Animals which apparently depend at least in part on this sense for communication at night include grasshoppers, crickets, some ants, mosquitoes and some beetles; along with the vertebrate frogs, tree-frogs, alligators, owls, goatsuckers, bats, shrews, mice, foxes, coyotes, howler monkeys, beavers, cats and a legion of others.

It must be remembered that many sounds are produced and heard by other animals that we can not hear, because they are too high or too low in pitch. This is especially true in the insect realm. Further, the kind of sound to which the human mind adjusts itself differs from that which is most significant to the animal. Man is rather little interested in the sounds which the things themselves produce and which are meaningful for the animal. The sounds which most often concern man are the sounds of organized speech which merely refer to objects and happenings.

Light production and the sense of sight have an obvious relationship at night. Light is produced by the fireflies and elater beetles and their larvae, by some other insects and by a number of other animals. This phenomenon is really of wider occurrence than is usually realized.

The photogenic organs of fireflies consist of granular cells enclosed in a network of fine air-carrying tubules or tracheae. These cells have the power of secreting a substance which is luminous when acted upon by oxygen from the tracheae in the presence of moisture. Fundamentally, this effect seems to depend upon a luciferin-luciferase reaction. The mass of branching air-tubes or tracheae makes possible rapid oxygenation and the resulting short quick flash of the fireflies. The rate of flash may be modified by temperature and also seems to be subject to direct nervous control. Light production is sometimes considered as simply a by-product of metabolism. Occasional synchronous flashing of fireflies in a given area, and the employment of flashing in mating behavior indicate that the light produced by one individual is perceived by others and that they are influenced by it.

Among various animals the light produced ranges from green to various shades of red, purple and violet. In some species, several colors or shades are emitted by the same organ at different times or by different organs on the same individual. According to Harvey, light is produced by species in almost forty orders of animals, chiefly marine. The jelly-fish and Portuguese-man-of-war, among the Coelenterates, and the Protozoan *Noctiluca* are familiar to any one who has cruised warm seas at night. Less familiar are luminous marine worms, brittle-stars, corals, squids and various other mollusks. Many of the deep-sea fish have batteries of luminescent organs, in line from head to tail, outlining eye and mouth, decorating fins and feelers. They live in constant darkness, in the cold depths where the sun's visible rays can not penetrate. Among these forms blue and green are colors of light commonly displayed. In general, it may be said that among animals the production of light is probably never necessary, even if occasionally useful. Probably it is all visible light, and it is produced apparently without the liberation of any heat.

In considering the possible uses of photogenic organs to the animals which possess them the following ideas suggest themselves. The congregating of individuals may be assisted by light production. Where the luminous organs have a definite pattern, as in certain fishes, recognition of individuals may be facilitated. Perhaps enemies are frightened away by light produced unexpectedly, through the action of organs under nervous control. The luminous "eyes" of some adult click-beetles are thought by some persons to be of "horrifying" intent. Again, the light may conceivably serve as a lamp, enabling deep-sea animals to find their way about. Or the light may be used as bait to attract prey. Thus the "fishing frog," a deep-sea fish, has a luminous pendant on the end of a fishing-pole arrangement projecting in front of its cavernous mouth. Small fry venturing near to investigate would certainly be in danger of immediate engulfment. As already noted, the rate of flash in the fireflies and glow-worms is reported to have a part in sex attraction. Some fish are said to be luminous only during the breeding season.

From a broader standpoint, it can be said that the influence of light is quite marked in most animal forms. Daytime insects accustomed to sleep at night are less active or quiescent on cloudy days. Moonlight tends to enliven daytime forms at night. Thus we have the calling of day birds and the voicing of some typically daytime mammals at night. The attraction of insects to artificial lights at night is a familiar phenomenon.

Opportunity for the employment of the sense of sight at night is quite limited in comparison with its daytime usefulness. However, some animals can apparently see quite well, even when starlight only is available. Frequently nocturnal animals possess eyes equipped with a reflecting tapetum behind the visual cells, by means of which faint light rays are caused to pass back through the retina a second time. Nocturnal vertebrates tend to have relatively large eyes. That eyes are subject to light adaptation is further testified by the fact that well-established cave animals usually have degenerate eyes or are eyeless.

Such an analysis still leaves much of a feeling of mystery about the lives of animals displaying the nocturnal habit. They seem to belong to another world, and it is a realm that entices fancy and challenges interest. More definite knowledge would probably not lessen our interest in the lives of creatures whose accustomed sphere of activity is so different from our own.

THE COURTSHIP DISPLAY OF THE FLIGHTLESS CORMORANT[1]

By MALCOLM DAVIS and HERBERT FRIEDMANN
NATIONAL ZOOLOGICAL PARK—UNITED STATES NATIONAL MUSEUM

In the spring of 1934 we observed a pair of flightless cormorants, *Nannopterum harrisi* (Rothschild), members of the bird collection at the National Zoological Park at Washington, D. C., indulging in a series of what seemed on casual glance to be "queer" maneuvers. On closer observation during 1934 and 1935 these grotesque movements appeared to take the form of a courtship display. Inasmuch as the literature, as far as we have been able to determine,

[1] Published by permission of the Secretary of the Smithsonian Institution.

does not reveal any account of these peculiar posturings, we have prepared the present description.

The pair of birds occupy an outside, moat-enclosed, barless cage that has in its center a sizable little artificial pond. Here the pair has remained out of doors during even the coldest weather that Washington experienced in the winter, 1934–35 Although normally birds of equatorial waters, they were adaptable enough to adjust themselves and to thrive under temperature conditions very different from those of their native habitat.

Courtship began early in the spring, in the first warm days of March, and continued with undiminished frequency through the spring and early summer months, gradually becoming more restricted to the morning hours late in August and terminating in early October. At first there seemed to be no definite time of day for displaying, but the birds indulged in it on and off at intervals of twenty minutes or so during the day (the birds were under more or less frequent observation from 9 A.M. to 5 P.M.), ceasing only at feeding time (at 2 P.M.). As the summer passed, the displays became less frequent in the afternoon and gradually became largely restricted to the morning hours.

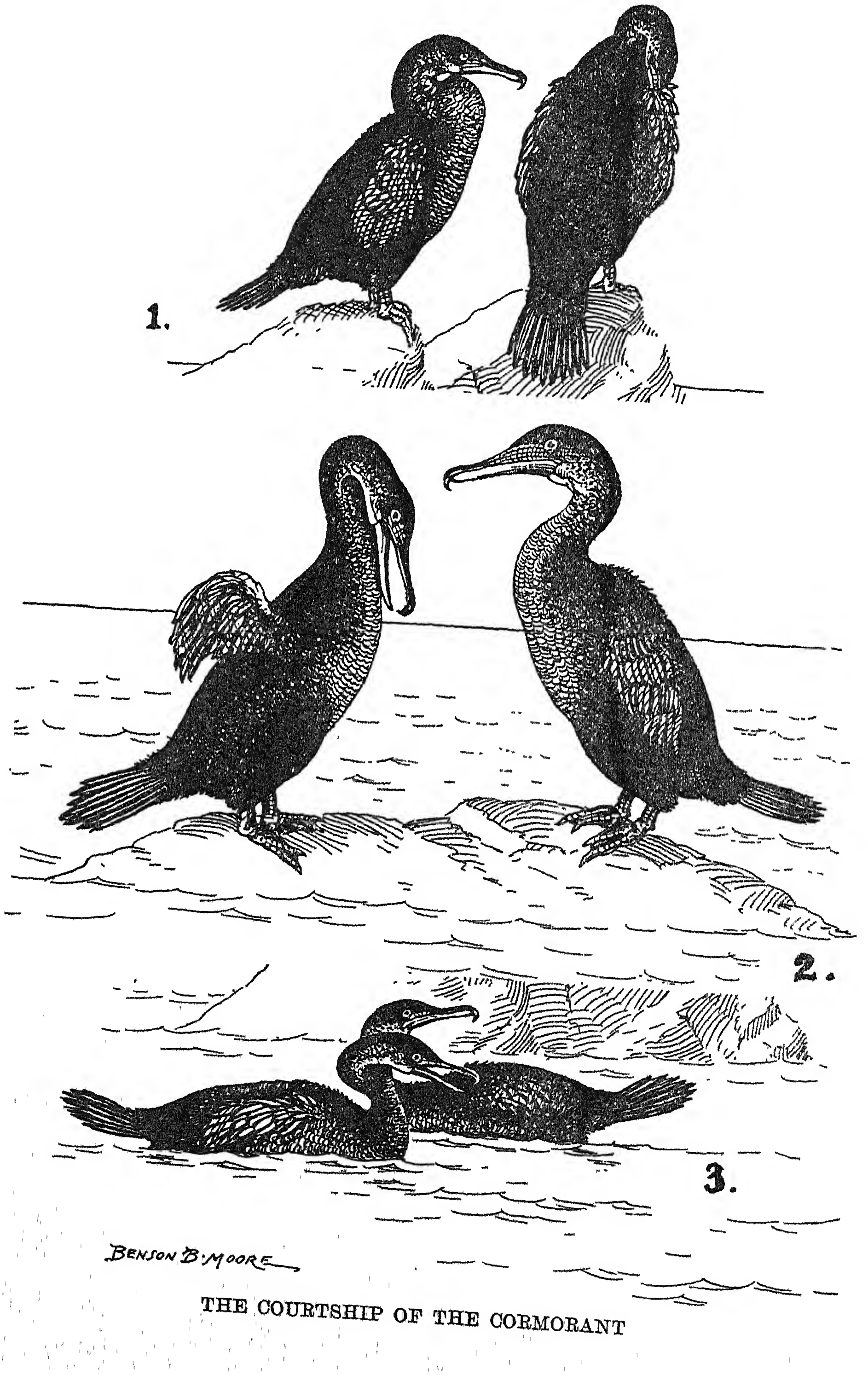
The accompanying sketches, drawn by Mr. Benson B. Moore from observations in the National Zoological Park, and the photographs taken by the senior author, illustrate the following description of the courtship performance. It may be stated at the outset that during all the movements, the breasts of the birds are continually throbbing rapidly. Sketch number 1 shows the sleeping female and the male aroused and about to begin courtship. The latter then attempts to waken and attract the attention of the hen by walking around her with a slow and rather heavy tread. His wings are raised, his neck arched, as shown in sketch number 2, and he utters the typical harsh, guttural, croaking call of the species. This usually succeeds in wakening the female. Both birds then take to the water and spin about in a small circle facing toward each other. They often separate a little, widening the diameter of the circle, but quickly come together again, as in the upper photograph. During this time both birds continually utter their low, somewhat quivering, guttural calls. If they happen to come near a stick or other object in the water, either of the birds may seize it and then continue spinning about with it in its bill.

Gradually the birds come closer and closer together, as in the lower photograph, and finally entwine their necks as in sketch number 3. During this stage, which may last for a couple revolutions of the spinning performance, their cries become milder. The pair sometimes circle about in the pond for as much as two minutes, then part, swimming separately for a short while, only to join again with louder and apparently more excited cries, when the whole performance is gone through again.

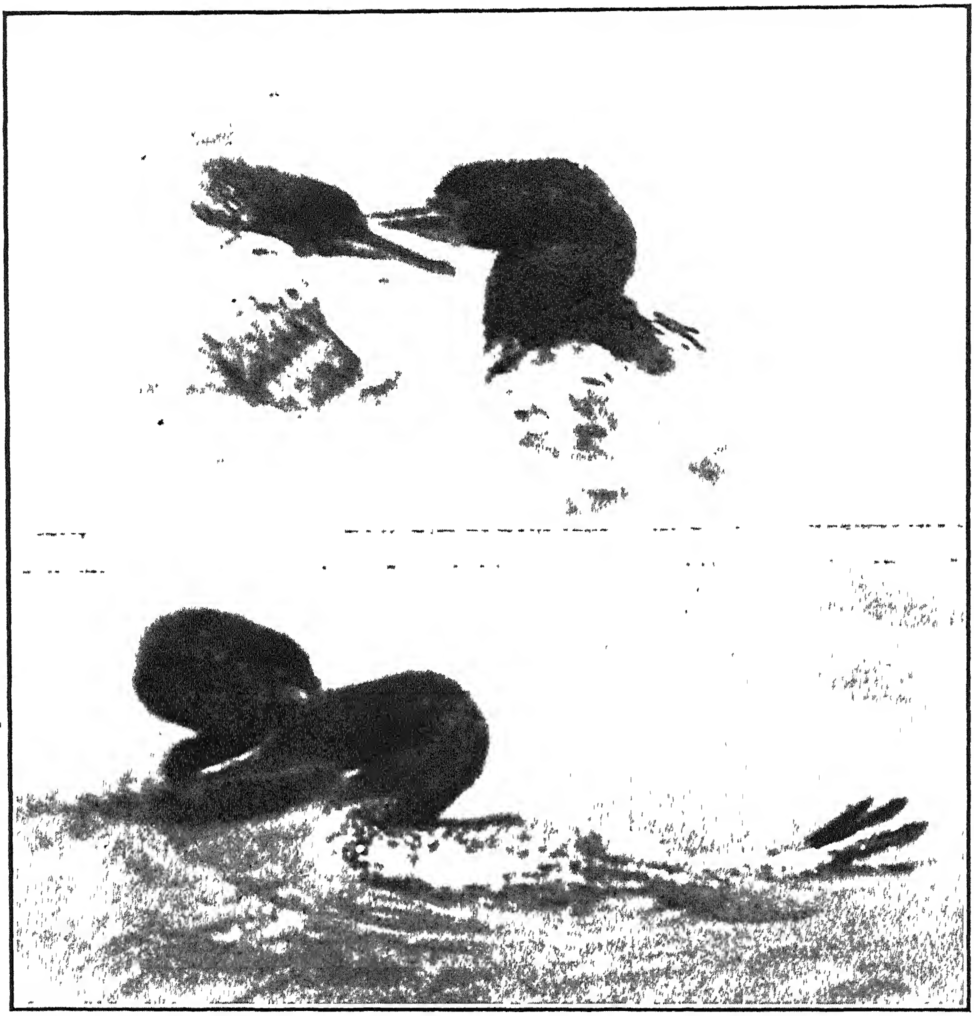
This courtship behavior is sometimes followed by attempts at copulation. No attempts were made except after such display posturing. Intercourse is attempted both in the water and on land, but, as far as our limited observations go, more often in the water. In this respect, as in the courtship itself, this flightless species differs from the species of *Phalacrocorax* written on by Portielje[2] and by Lewis.[3] The male would climb easily on the hen, almost submerging her, and attempt coitus. The female was always passive in our observations, showing no resistance to the male. Occasionally the female would swim to shore immediately after the spinning performance, whereupon the male would follow closely in her wake and attempt copula-

[2] "Ardea," pp. 107–123, 1927.

[3] "*Natural History Double-crested Cormorant*," pp. 23–27, 1929.



THE COURTSHIP OF THE CORMORANT



COURTSHIP IN THE WATER

tion on shore He would attempt to place his right foot on her back, at which she would crouch as if it had been a definite, prearranged signal, and allow him to mount her Copulation was observed only a few times, although the courtship display was indulged in day after day for many months It undoubtedly took place numbers of other times but went unseen. The birds made no attempt to build a nest from the ample supply of straw and twigs given them, and no eggs were laid.

On the whole, the female appeared to make advances to the opposite sex in the same manner, frequency and intensity as the male The two sexes could be distinguished by the heavier, thicker neck of the male. At times the birds fought with each other, but the scraps were of short duration and appeared to have no lasting effects

BUST OF SIMON NEWCOMB

THE DISTINGUISHED ASTRONOMER, UNVEILED ON MAY 28 IN THE HALL OF FAME OF NEW YORK UNIVERSITY. IT IS THE WORK OF FREDERICK MACMONNIES.

THE PROGRESS OF SCIENCE

BUST OF SIMON NEWCOMB IN THE HALL OF FAME

DISTINGUISHED American astronomers honored the memory of Simon Newcomb at ceremonies in the Hall of Fame on the campus of New York University at the end of May A bronze bust of Newcomb, first astronomer to be elected to the Hall of Fame, was unveiled in the section of the Colonnade dedicated to scientific men The bust is the work of Frederick MacMonnies, American sculptor, and is the gift of Dr Ambrose Swasey, Cleveland manufacturer of astronomical instruments and a close personal friend of Newcomb during the latter's lifetime

Simon Newcomb achieved a distinguished place among the astronomers of his day because of the wide extent and importance of his labors, the variety of subjects of which he treated and the unity of purpose which guided him throughout He set himself the gigantic task of building up, on an absolutely homogeneous basis, the theory and tables of the whole planetary system and labored at that project for over twenty years. The results of Newcomb's investigations have been adopted more or less completely by all countries for use in their nautical almanacs He was also known for his work in connection with the theory of the motion of the moon, as a result of which he made important additions to celestial dynamics. He published important works on the Uranian and Neptunian systems and compiled a new catalogue of standard stars

Dr. Newcomb was born in Wallace, Nova Scotia, on March 12, 1835 He became a resident of the United States in 1853 and graduated from Harvard University in 1858, where he studied mathematics and astronomy. In 1861 he became professor of mathematics in the United States Naval Academy and was placed in charge of the 26-inch telescope erected in Washington in 1873 In 1884 he became professor of mathematics and astronomy at the Johns Hopkins University During his lifetime the astronomer was honored by many European universities and scientific societies He died at Washington on July 11, 1909, and was given a military funeral, having been made a rear admiral by Act of Congress in 1906

Presentation of the bust of Simon Newcomb was made by Professor Harlow Shapley, of Harvard College Observatory; Dr W. W. Campbell, president emeritus of the University of California and director emeritus of the Lick Observatory, paid oral tribute to Newcomb's work. In the absence of Dr. Anita Newcomb McGee, eldest daughter of the astronomer, the bust was unveiled by her sister, Mrs. Emily Newcomb Wilson, who is registered by New York State as a consulting psychologist.

H. W.

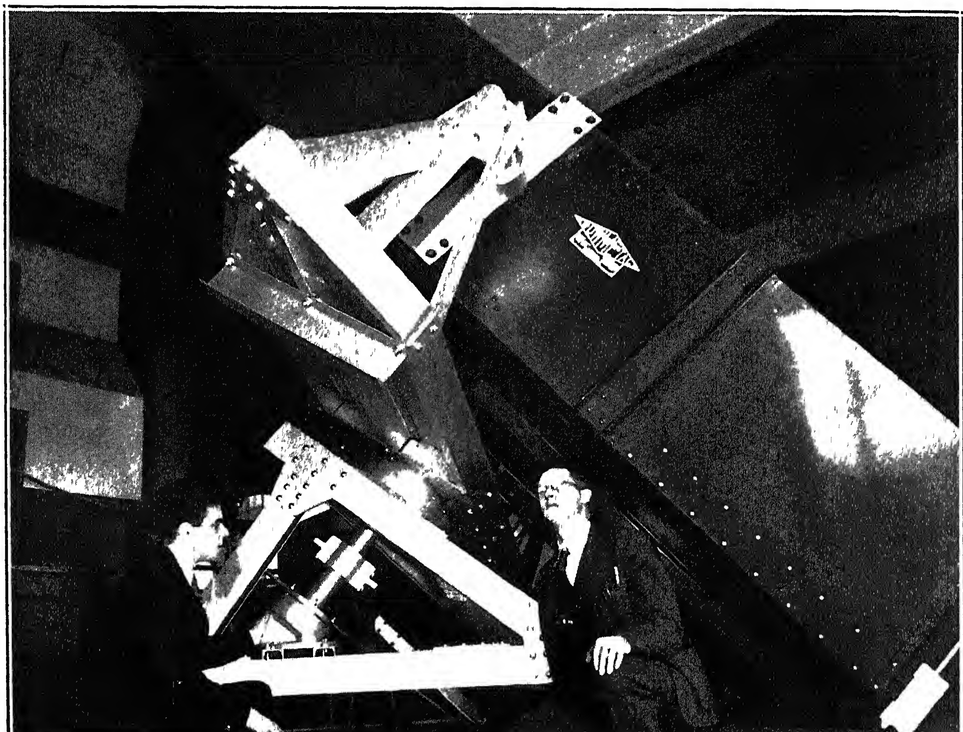
THE HARVARD–M. I. T. RUSSIAN ECLIPSE EXPEDITION

HARVARD OBSERVATORY, in collaboration with the Massachusetts Institute of Technology, has sent a joint expedition to Soviet Russia to observe the total eclipse of the sun on June 19, which will not be visible from the western hemisphere The belt of totality, which is about seventy-five miles wide, starts in the Mediterranean and then swings northeastward across Greece and the Black Sea. The well-known Siberian cities, Omsk and Tomsk, lie close to the central line. On the eastern end the track crosses Manchuria and northern Japan, ending at some point well out in the Pacific Ocean.

The Harvard-Technology group accepted the invitation of Dr. Boris P. Gerasimovic, formerly an associate at Harvard Observatory and now director of Poulkova Observatory at Leningrad, to join one of the Russian eclipse parties. The site finally chosen is near the town of Ak-Bulak, in the southern Ural Mountains, north of the Caspian Sea. The nearest large city is Orenburg, about seventy miles to the north. While Tomsk is a more favorable location, in certain respects, since the sun is higher in the sky, the collected weather reports indicate that the chances for clear weather are appreciably greater at Ak-Bulak, where totality occurs at 8:00 A. M., local time, with the sun 36 degrees above the horizon.

Dr Donald H. Menzel, of the Harvard Observatory, is in charge of the expedition and is assisted by Dr Joseph C. Boyce, of the Massachusetts Institute of Technology. Henry Hemmendinger, graduate student at Harvard, and a considerable group of technical assistants accompanied the expedition. The eclipse program is chiefly spectrographic The observers plan to obtain spectrograms of the chromosphere and of the corona over a wide range of wave-lengths, with special emphasis on the infra-red region of the spectrum, where present knowledge is only fragmentary.

"Chromosphere" is a technical name for the outer layers of the sun. It is a sort of rarefied atmosphere that envelops the sun's shining surface. Observations



APPARATUS FOR PHOTOGRAPHING THE SPECTRUM OF THE CHROMOSPHERE
LEFT TO RIGHT: HENRY HEMMENDINGER AND DR. DONALD H. MENZEL, DIRECTOR OF THE EXPEDITION INSIDE THE SPECTROGRAPH BOX WILL BE HOUSED FOUR PLANE GRATINGS, POLISHED METAL SURFACES RULED WITH 15,000 LINES TO THE INCH, WHICH WILL BE USED, EACH WITH A SEPARATE LENS AND CAMERA, TO PHOTOGRAPH THE CRESCENT OF THE ECLIPSED SUN AND THE CORONA.

of it are best obtained at time of eclipse, when the brilliant sun is hidden and only this atmosphere protrudes from behind the moon There are many problems in connection with the chromosphere, such as its chemical composition, the source of its excitation and the nature of its structure. This atmosphere is not uniform and appears to be composed of myriads of filaments, shot geyser-like from the surface of the sun

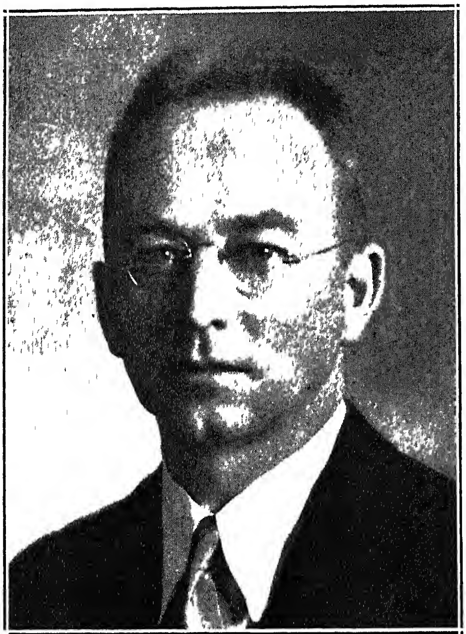
The solar corona lies above the chromosphere and presents additional mysteries The chromosphere is known to consist of hydrogen, helium, calcium, iron, etc., all in the gaseous state, identified by matching colors in its spectrum with colors given off by known elements. But not a single one of the many known coronal lines has been positively identified. Astronomers at one time suspected that a new and terrestrially unknown element existed in the corona, and gave to it the name "coronium" That theory became no longer tenable when the chemists had filled all the gaps in the table of elements. Scientists now believe that coronium is some well-known substance, masquerading with the help of the peculiar conditions that exist in the corona A couple of years ago Drs Menzel and Boyce provisionally suggested that oxygen might be responsible, but additional data are required to settle the question one way or the other. Study of the infra-red coronal spectrum may provide the answer.

J. J. R.

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

The National Academy of Sciences held its seventy-third annual meeting during the last week in April at its home in Washington, D C. The academy convenes twice each year and has done so regularly, with two exceptions, since its incorporation by Congress in 1863. The annual meeting is held in April in Washington and the autumn meeting elsewhere. New members are elected only at Washington; medals for achievements in science are awarded at both the annual and the autumn meetings. At each there are public sessions for the presentation of papers on the results of original research in different fields of science; the list of papers on each program reflects in a measure the state of development of science at that time. The complete list of papers read before the academy since the Civil War affords an indication of the progress made in science during this period.

At the business meetings the academy members consider current business items and receive reports on the work done by the academy on special problems submitted by different departments of the government for solution and advice. This procedure is in keeping with the charter of the academy and with the interpretation given it by Joseph Henry in 1867 in his report as president of the academy, in which he stated: "The objects of this association are principally to advance abstract science and to examine, investigate and experiment upon subjects on which information is desired by the Government." The purposes of the academy at the time of its founding were twofold, namely, "to afford recognition to those men of science who had done original work of real importance and thereby to stimulate them and others to further endeavors; and to aid the Government in the solution of technical scientific problems having a practical bearing on the conduct of public business" These two objectives have remained unchanged to the present time and are of vital importance to the academy. Election to membership in the academy is a public recognition of original research work in science; it also implies that the



DR J. L. WALSH
ASSOCIATE PROFESSOR OF MATHEMATICS, HARVARD UNIVERSITY.

DR. ROBERT S MULLIKEN
PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO.

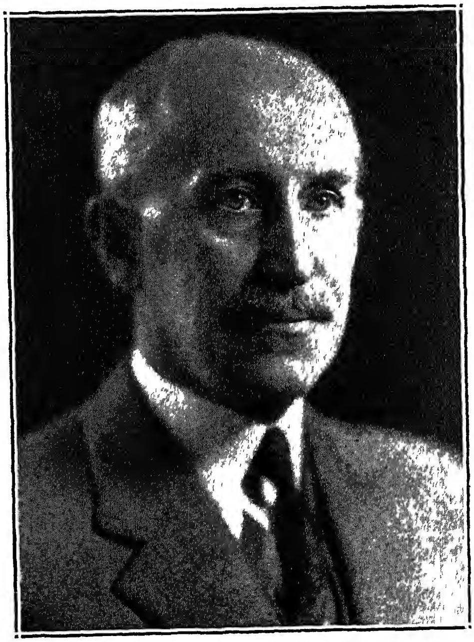
new member is competent to serve the academy effectively in the solution of problems of interest to the government Acceptance of membership places a responsibility on the new member to aid the academy in these problems, should the need arise.

The scientific sessions of the recent annual meeting were well attended and the papers aroused interest and discussion The distribution, among the sciences, of the 45 papers on the program was mathematics, 3, astronomy, 4; physics, 8; engineering, 1, chemistry, 2, meteorology, 2; geology, 5, biology, 1, zoology, 2, physiology, 6; pathology, 1; medicine, 2; psychology, 4; anthropology, 1 Of these papers 31 were read by academy members and 13 by non-members In addition 4 biographical memoirs were read by title In the presentation of his paper each speaker made a serious effort to emphasize the essential features of his work, rather than the details, with the result that the papers, on the whole, were clear and easily understood. However, several of the papers were highly technical in character and not easily followed, except by the specialist.

The number of papers in physics indicates the continued wide-spread interest in this field. Drs. E O Lawrence and J M. Cook described the successful transmutation of platinum into radioactive platinum and iridium isotopes and thence into gold through bombardment by five million volt deuterons emerging from the cyclotron. With the improved cyclotron they have succeeded in obtaining a beam of alpha particles (nuclei of helium) issuing at 11 million volts and one tenth of a microampere, thus affording a most powerful instrument and method of attack on problems in nuclear physics Drs R A Millikan, H V Neher and Serge Korff described tests made at high altitudes (29,000 feet) in Peru and at Manila, P. I, with automatic Neher recording cosmic ray telescopes.

The recorded great increase in ionization with height indicates that the photonic component is an important element of cosmic rays. Dr G. R Harrison described a method, based on new automatic instruments, for the systematic determination of wave-lengths and intensities of the spectral lines of the chemical elements With this arrangement several million spectral lines are being measured with adequate visual control The final results will be of great value to workers in different fields of spectroscopy In the discussion of this paper Dr R W Wood called attention to gratings which he has recently ruled on a thin aluminum film coated on a thinner film of chromium on a glass surface These gratings are more easily ruled than speculum gratings, reflect more light in the ultra-violet and are practically free from the familiar ghosts of speculum gratings By etching a ruled aluminum film grating on glass Dr Wood has obtained excellent glass gratings Dr A W Hull described the results of a long series of experiments on changing direct current to alternating current by means of thyratrons with special reference to the transmission of electric power With the apparatus now available he found no difficulty in changing currents of 200 amperes at 15,000 volts by the new method from direct to alternating current and *vice versa*. Dr R D Evans spoke on new radioactivity detection technique applied to the study of radium poisoning Dr Simon Flexner emphasized the possibility of second attacks and reinfection in poliomyelitis. Dr Florence R Sabin described experiments and observations on the development of the cells of the blood and bone marrow in the rabbit Dr R. M Yerkes and J H Elder presented the results of a long study on the sexual and reproductive cycles of the chimpanzee. This was followed by a paper by Drs. H. W. Nissen and M. P. Crawford on altruism

DR. I S BOWEN
PROFESSOR OF PHYSICS, CALIFORNIA INSTITUTE OF TECHNOLOGY.



DR. ORVILLE WRIGHT
DIRECTOR, WRIGHT AERONAUTICAL LABORATORY.

Sidney V. Webb

DR. W. F. GIAUQUE
ASSOCIATE PROFESSOR OF CHEMISTRY, UNIVERSITY OF CALIFORNIA.

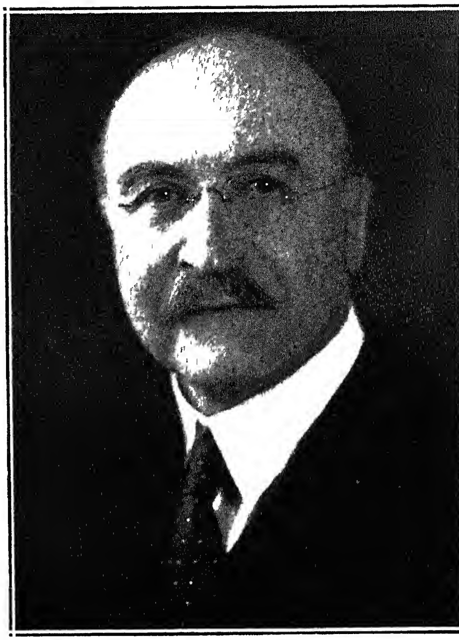
and cooperation among chimpanzees, illustrated by moving pictures Dr. Franz Boas analyzed the effects of American environment on immigrants and their descendants, as he has studied them over a period of 25 years. He has found "that the pressure exerted by social environment brings it about that the behavior of whole populations tends to be moulded by the pattern of the dominating society." Dr. C E Seashore reported upon the progress made in the study of the psychology of the vibrato in the rendering of music This study has been continued over a period of years and has involved an analysis of the three kinds of vibrato, the devising of suitable instruments for the measurement of the phenomena, the gathering and analysis of the data of measurement and the discussion of the results from a psychological standpoint. Dr W. D. Urry presented the results obtained by the application of the helium method to problems of Pre-Cambrian chronology. Dr R. W. Wood described some new effects ob-

DR. WALLACE H. CAROTHERS
RESEARCH CHEMIST, E. I. DU PONT DE NEMOURS AND COMPANY.

DR. ELIOT BLACKWELDER
PROFESSOR OF GEOLOGY, STANFORD UNIVERSITY.

tained with high explosives and showed unexpected behavior and flow of metals under these conditions. Dr. Linus Pauling and C. D Coryell presented a paper on the results of magnetic measurements obtained on blood and hemoglobin solutions and indicated their significance with reference to the magnetic properties and structure of hemoglobin and related substances. Drs. E. N Harvey, A. L Loomis and G Hobart described the results of measurements of electrical potentials from the human brain with special reference to the 10-cycle rhythm which appears in a person resting quietly and to the disturbances which arise when the person is disturbed.

The Monday evening public lecture was given by Dr. A. L. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington, on the subject, "The Hot Springs Problem in Yellowstone Park." Drs Day, Allen and Fenner have been at work on this



Underwood and Underwood

DR. L. H. BAEKELAND

HONORARY PROFESSOR OF CHEMICAL ENGINEERING, COLUMBIA UNIVERSITY.

From a Portrait by Edmund Giesbert

DR. EDWIN O. JORDAN

PROFESSOR OF BACTERIOLOGY, UNIVERSITY OF CHICAGO.

DR. WM. C. ROSE

PROFESSOR OF PHYSIOLOGICAL CHEMISTRY, UNIVERSITY OF ILLINOIS.

Bachrach
DR. EDMUND W SINNOTT
PROFESSOR OF BOTANY, COLUMBIA UNIVERSITY.

Bachrach
DR. ALEXANDER FORBES
ASSOCIATE PROFESSOR OF PHYSIOLOGY, HARVARD MEDICAL SCHOOL.

problem for the past seven years and have studied it from many different standpoints with the result that new conceptions regarding the nature of hot springs and geysers have been developed which are of importance in connection with the metamorphism of rock masses and with the rôle played by underground and magmatic waters in modifying the materials through which they pass. The lecture was illustrated by superbly colored lantern slides and by motion pictures showing geysers in action and allied phenomena

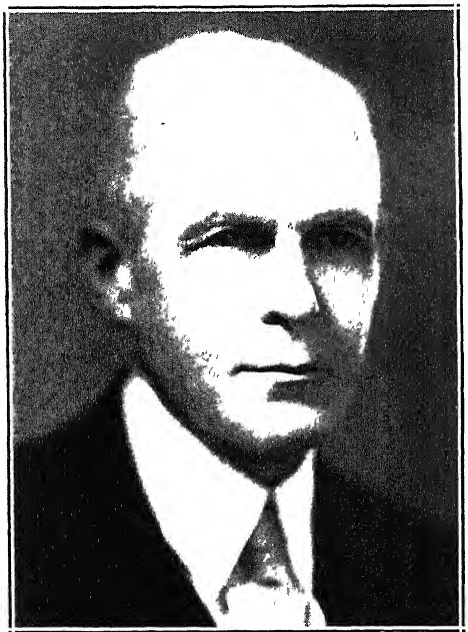
The average attendance at the sessions, in the auditorium was 350, in the lecture room 185 and at the evening lecture 300

On Tuesday afternoon academy members were invited by Dr R D. W. Connor, archivist of the United States, to visit and inspect the new Archives Building of the government The 50 members and guests who accepted the invitation were shown over the building. The facilities for receiving, cleaning, storing, filing and making accessible valuable documents were demonstrated, and the purposes of the project were explained in detail. The visit was extremely interesting and was much appreciated by the visitors.

At the annual dinner on Tuesday, President Lillie delivered, at the request of the committee on arrangements, a brief address on the status of the academy and on its accomplishments during the past year. The concluding paragraph of his address emphasizes the relation of the academy to research work in science

The Academy remains firmly founded on the bed-rock of scientific research, and science in confidence in orderly thought, whether for the understanding or control of the processes in nature and in man. If any change of attitude is to be noted, it is an increased state of consciousness of public and social responsibility, which developed rapidly under the stress of the great war, and of these recent times of economic depression, stimulated by an awakened public con-

fidence and interest in science There is no present danger, in our country at least, that scientific discovery and thought should be underestimated or suppressed, this condition should heighten our sense of responsibility to see that its power and authority are not exaggerated. The true friends of science recognize that limitations are set in nature and in the mind itself to scientific progress. We can not predict its rate, direction or extent for any considerable period of time. Yet I think that experience should give us confidence to claim that the conquering spirit of science is one of the strongest components of ideal social processes, and always will be



Bachrach

DR. WARREN H. LEWIS
DEPARTMENT OF EMBRYOLOGY, CARNEGIE INSTITUTION OF WASHINGTON AT JOHNS HOPKINS UNIVERSITY

This was followed by the presentation of two medals The Agassiz Medal for Oceanography, awarded to T. Wayland Vaughan, of the Scripps Institution of the University of California, La Jolla, in recognition of his investigations of corals, foraminifera and submarine deposits, and for his leadership in developing oceanographic activities on the

DR. CLARK L. HULL
PROFESSOR OF PSYCHOLOGY, YALE UNIVERSITY

Science Service

DR. A. V. KIDDER
CHAIRMAN OF THE DIVISION OF HISTORICAL RESEARCH, CARNEGIE INSTITUTION OF WASHINGTON.

Pacific Coast of North America. The presentation address was made by Dr. Henry B. Bigelow, who was chairman of the committee which recommended the award at the last annual meeting. The Public Welfare Medal of the Marcellus Hartley Fund, awarded to Dr F F. Russell, formerly director of the International Health Division of the Rockefeller Foundation and at present lecturer in preventive medicine and hygiene and epidemiology at Harvard University, in recognition of his work on the etiology of yellow fever and studies of epidemic areas The presentation address was made by Dr. Max Mason, president of the Rockefeller Foundation.

At the business session Dr. Arthur Keith, geologist of the United States Geological Survey, was reelected treasurer for a period of four years; Dr. Simon Flexner, of the Rockefeller Institute for Medical Research, and Dean J. B. Whitehead, of the Johns Hopkins University, were elected to the council for a period of three years. Fifteen men, whose portraits are here reproduced, were elected to membership in the academy.

The present membership of the academy is 293, with a membership limit of 300; there are 41 foreign associates, with a limit of 50 At the annual meeting 117 members and one foreign associate were in attendance.

The autumn meeting of the academy will be held this year on November 16, 17 and 18 at the University of Chicago.

F. E. Wright,
Home Secretary

THE AMERICAN CHEMICAL SOCIETY AT KANSAS CITY

The ninety-first meeting of the American Chemical Society was held from April 13 to 17 in Kansas City, under the presidency of Professor Edward Bartow. The two thousand visitors included representatives of Great Britain, the Netherlands and Switzerland. A program of some three hundred scientific papers was supplemented by trips to local industrial and municipal plants.

Chemistry presents a picture of ever-increasing specialization. The members of the nineteen subdivisions scarcely speak one another's language Yet a newly formed section, *Deuterium*, occasioned the liveliest interest This is due to the fact that Professor Urey's discovery of "heavy hydrogen" was not only of profound theoretical significance, but also has proved to have far-reaching applications For example, the biochemists can study physiological processes more accurately than ever before, through the earmarking of synthetic drugs and foodstuffs with deuterium. Investigations in the field of catalysis, of which our knowledge is all too empirical, will be expedited through the application of this powerful new tool.

Two investigators from the University of Wisconsin, Dr. N. F. Hall and T. O. Jones, reported a series of determinations from which they concluded that the distribution of deuterium on the earth's surface was 1 part in 6,500 of water

Every reader of the press is aware of heavy hydrogen, but it is quite another matter for the invariability of oxygen to be questioned. The layman may still rest assured that in any sample of water he is likely to meet, the ratio of oxygen to hydrogen will be 16 to 1, but a variation from this ratio of a few parts per million is of the greatest concern to the scientist The isolation of isotopes has long since ceased to be a one-man job, for Dr. F. W. Aston, of the University of Cambridge, and Dr Malcolm Dole, of Northwestern University, have now made the startling discovery that the atomic weight of oxygen is not invariably 16. An isotope of weight 18 exists,

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and is in greater concentration in the atmosphere than in the ocean. To account for this, the hypothesis is advanced that an interchange of oxygen atoms takes place in the stratosphere under the influence of ultra-violet light. Molecules of water composed of hydrogen and "heavy oxygen" lose the latter and acquire atoms of conventional oxygen instead.

Another new section was microchemistry, which comprises far more than the application of the microscope to chemical investigations. It is used in blood analysis, detection of new hormones, exposure of fraud, catalysis, etc. A whole new technique has been elaborated, and the tools employed consist of a balance sensitive to one millionth of a gram, micro-distilling flasks, micro-pipettes and sensitive and highly specific reagents. Of particular interest to consumers was the announcement of a new reagent, *dithizone,* used by the Food and Drug Administration for the detection of lead in fruits.

The stimulation of agriculture through increased use of the soybean was con-

sidered important enough for a special symposium The 1935 crop was 39 million bushels The potential utilization has been only slightly explored, but already soybean meal is eaten by live stock and by man as well, in products such as bread, candy, macaroni, seasoning powders and sauces. The paint and soap industries have found the oil (a by-product of the meal) to be capable of wide application.

Vitamin research is proceeding apace, as would be expected. Of special interest was the report of the staff of the Oklahoma Agricultural and Mechanical College that cod liver oil contains vital nutritive constituents other than vitamins A and D. The authors were conservative in their statements, but if further work substantiates their present results, it will demonstrate what has long been suspected, namely, that the so-called vitamin pills can not be regarded as a substitute for cod liver oil.

Other work in the field of nutritive and medicinal chemistry included studies of goiter-preventing foods; aluminum hydroxide in removing fluorides from water; the rôles played by iron and copper in combatting anemia; and the rôle of sulfur (in combination, as the amino-acid cystine) in preventing arthritis.

Increased utilization of coal before our oil reserves have been depleted was forecast by the work of Dr R. S. Asbury, of the Carnegie Institute of Technology. Coal can be liquefied and used in place of oil by combining it with hydrogen In order to hydrogenate coal, it must be in solution and, surprisingly enough, Dr Asbury succeeded in dissolving 85 per cent of a sample of bituminous coal in tetralin, a cheap solvent derived from naphthalene Elucidation of the chemical composition of coal may be expected as a result of pushing this work to its logical conclusion

The increasing complexity of chemistry makes it imperative to choose the subject-matter of a high-school course skilfully. In the section of chemical education, it was suggested that inasmuch as the great majority of high-school chemistry students will never open another text-book, they should not be enmeshed in the intricacies of atomic structure, but should instead be taught the practical applications of the subject For example, they should be taught how simple are the mixtures used in making cosmetics, dentifrices and proprietary medicines They should learn to regard all pseudo-scientific advertising with complete skepticism. In that way the purveyors of fraudulent preparations will disappear without the necessity of a law with teeth in it.

THOMAS B GRAVE

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